# THE HUMAN FACTOR IN INDUSTRY.

*Presidential Address by R. H. Youngash, M.I.P.E., President, Birmingham Section.*

IT gives me very great pleasure to report for the second time at the Annual Meeting of our Section that the Institution continues to make satisfactory growth and progress. The number of members has now reached the 900 mark, out of which, Birmingham has contributed 200, an achievement which, bearing in mind the difficult times we are passing through, we have every reason to be proud of, and also a clear indication of the increasing interest being taken in production problems and the work of the production engineer. You will already be aware that two new sections have recently been inaugurated, Leeds and Sheffield; it is not too much to say that these have started under the best possible auspices and I am sure they will not only be of considerable service to members in those districts but will reflect great credit on the Institution as they develop.

The formation of the Graduate Section will also be fresh in your minds and we must all feel pleased that Birmingham has had the honour of breaking new ground in this direction with a section entirely and exclusively for the younger members. We expect that the examination which takes place very shortly will add further numbers to our membership, and from this small beginning develop a source cf associate and full members at a later date. It may also be opportune to draw your attention to the fact that these young men will have been trained for production engineers according to a syllabus prepared by Education Authorities jointly with the Institution, and whose careers have been planned so far as possible to make them production engineers from the commencement. The Graduate Section constitutes the tenth local section and in a short time this Institution will have more local centres than any other engineering society.

During the past season the standard of our lectures has reached a very high level and while it is perhaps invidious to single any particular one out, I think you will agree that both the Economic uses of Tungsten Carbide Tools and Drop Forging Procedure were extremely good and had the added charm of being the work of members of the Institution. Birmingham is proud to have such members as Mr. Garnett, Mr. Field, and Mr. McNab. Our informal

*19th April, 1933 ( Vol. XII, No. 8, August, 1933).*

discussions have also proved interesting and instructive. I am anxious, however, not to convey an impression that Birmingham had all the good lectures this session. Members who read the Journal will know that those delivered to other sections were also of a very high standard, and the whole series were chosen from the best possible subjects, were dealt with in an extremely interesting and capable manner by eminent members of the engineering profession, no less than 15 of whom were members of our own Institution, a feature your Council is anxious to see extended. The programme for next session will include at least 70 lectures and if, as is anticipated, one or two further local sections are formed the total will be nearly100. Very few bodies of even larger size can claim so wide a range of activity in the matter of lectures and discussions, and it is interesting to know that the aggregate attendances at our lectures is over 6,000. To carry through the work of a normal session necessitates real hard work by the section committees, and no praise would be too great for the enthusiastic and businesslike way in which this work is done, and when I say that the aggregate attendances involved is no less than 1,400 you will realise the enormous amount of voluntary effort that is being expended in this way.

Your council is anxious to further the interest of the members in every possible way, great care is being exercised in the admission of new members to ensure that only men who possess the necessary qualifications and who are known and vouched for by members are admitted. The finances of the Institution are being zealously guarded and the proportion of its annual income expended on local sections is considerably higher than any other engineering institution, and no payments whatever are made in any form to lecturers, members of council, committee men, or any person outside head office staff. Without stinting any legitimate expenditure, rigid economy is being observed.

I should like to take this opportunity of reminding members that they will be welcomed at the Institution head offices whenever it may be convenient to call and that Mr. Hazleton and his staff will be glad to render any assistance in their power, and gratefully return thanks to Mr. Hazleton for the help and assistance I have received from him during my period of office as president of this section.

The subject I have chosen for my address to-night is extremely interesting and absorbing. To me it seems to follow quite naturally on the lines I took on a similar occasion last year, and was actually suggested by one speaker.

I find, at the outset, considerable difficulty in what I may call the "layout." The chronological order and sequences will probably be wrong, I shall not be able to explore any one point to a reasonably satisfactory conclusion, and I shall introduce elements you may consider outside the limits of the title ; but I feel sure you will bear

with me for two reasons, first, it provides a little variation from matters usually dealt with in our lectures; secondly, we, as production engineers, ought to examine so far as possible every factor having a bearing on production problems.

## Man's Attitude to His Employment.

Man alone of all the animal kingdom has been endowed by a beneficent Providence with reasoning abilities, the power to reconstruct the past and apply the lessons thus learned to forecasting the future. His attitude towards employment, therefore, to a large extent, will be influenced by his experiences of the past and his anticipations for the future; but also by his present surroundings and conditions, and as these change his outlook will also change. Other factors that have a bearing are hunger, family cares, love of craftmanship, personal gain, the desire for pleasure, and various emotions, and his attitude will be largely inspired by the predominant urge that impels him to follow some employment. He is naturally indolent or at anyrate spasmodic in his willingness to undertake any physical effort requiring close attention or even the expenditure of energy, although he may display amazing persistence when once having undertaken a particular task, and he needs a continual spur of some description for progress.

We must therefore conclude that there can be no fixed attitude in, at anyrate the majority of individuals, in fact we shall find them willing or unwilling, pleasant or sullen, energetic or lazy, according to the particular factor that looms largest on their horizon at the moment. The necessity for keeping these facts in view in our dealing with employees is of considerable importance and also point clearly to the advisability of intelligently considering what reactions are likely to take place when introducing fresh conditions or changes.

I have purposely avoided questions of health at this stage, though of course this has an important bearing on the subject, as time will not permit of any reference to this obvious factor to-night.

## Rules and Regulations.

Rules and regulations are an essential part of civilized life, it is therefore not surprising that they are unavoidably present in industrial life, in fact they have an important bearing in developing and moulding man's attitude in his employment. We have a problem of considerable magnitude in framing and drafting the necessary rules and regulations in such a manner that they may be applied with the minimum amount of irritation and hardship but will at the same time secure the necessary order and discipline. It has at times been assumed that rules and regulations were inexorable like the laws of the Medes and Persians, but we know that like most things in this world they are subject to change and require

modification at times, it is not too much to say that to-day it is recognised that careful and intelligent consideration of changing conditions and the adjustment and re-adjustment of our rules and regulations are necessary, not so much perhaps as a genuine desire to avoid the mistakes of yesterday, as a part of a plan having a definite value which may be expressed in pounds, shillings, and pence, knowing that disgruntled or dissatisfied workers do not give the best return for the wages they receive. We must recognise that the old order of harshness has disappeared, that leadership is a better way than driving, although this is not to be interpreted as weakness or grandmotherliness, and that sound judgment and common sense will succeed even when all other methods have failed.

### Working Conditions.

Rules and regulations are of course closely related to working conditions and their interaction is easily followed. There is no doubt that generally speaking working conditions are better than they have ever been, the process of evolution is so clearly evident that most of us here to-night will have seen marked changes and advances, although much remains to be done. It is, however, curious to find that almost simultaneously with the advent of the factory system there came a conscious appreciation that something was wrong, progress was slow at first, but all the past history of factory life shows that there was a definite knowledge that there were defects in the system and a desire to secure improvements. The first Act of Parliament for instance on this subject was passed so long ago as 1844. In 1848 one mill owner was experimenting with shorter hours of work and made what to him was a momentous discovery, that he could obtain as much output in an eleven hour day as a twelve, and even in those early days gymnasiums and thrift societies, etc., in connection with works existed. It is also important to notice that these efforts were then, as now, being made by the employers and that generally speaking employees have made very little effort either individually or at a later date through their trade unions to improve anything outside rates of pay and matters immediately connected with wages. Working conditions play so large a part in production problems that it is imperative we should give full considerations to the question if we are to secure the best results from our employees.

It is not my intention to attempt to indicate what would be the improvements in working conditions, there is no limit to what may be accomplished in this direction and good conditions to-day become bad to-morrow. At the same time we should endeavour to avoid creating or permitting to exist known bad conditions because such conditions must definitely result in lowered efficiency.

### Rates of Pay.

I cannot avoid including a few remarks on this thorny subject and

would like to quote a paragraph from a book written so far back as 1893, the title being "The Economy of High Wages," by J. Schoenhof. He says, "Most of the strife between employers and workers would disappear if it were more fully recognised that a high rate of wages is all the time a powerful lever to low cost of production and its converse a high consuming power. A relatively high standard of living is required to make the labourer efficient, strong in body and mind. Without this labour remains economically more or less sterile."

This doctrine has been pushed to its logical conclusion in America, and it would be interesting to know what the writer of this book thinks if he is alive to-day. The conditions existing there at present do not seem to confirm his thirty year old theory, and there is no evidence that high or low rates of pay will of themselves ensure continuous employment or that high productivity necessarily means high consumption. There are many factors that affect rates of pay outside factory conditions, in fact the actual payment is in itself quite secondary. What is important, however, is the standard of living which any particular rate permits the recipient to enjoy. We cannot anticipate much change in man's attitude to this question so long as present day conditions prevail, and workers will continue to be influenced by circumstances affecting wages more than any other consideration, perhaps rightly, certainly naturally so, the incidence being greater during times of prosperity and lesser during periods of bad trade.

**Accidents.**

The enormous cost of accidents in pain and suffering, lost time, and compensation, make the problem of accident prevention one requiring the most serious consideration of all concerned. During 1931 there were 300 mutilations on power presses, and this in spite of the elaborate precautions that have to be taken to prevent such happenings. No doubt carelessness in some direction or other was the cause of most of these, but it is appalling to reflect on this disastrous result. One might expect to find successive generations of factory workers exhibit some intuition of dangers of this nature, but there seems no evidence that this is so, in fact, when you consider the continual recurrence of fatal accidents due to repairing containers that have held volatile fluids such as petrol, you are bound to conclude that we do not transmit the lessons we learn of this nature to our successors, and consequently we should increase our efforts to prevent such happenings by every possible means at our disposal. Under this heading we must also mention occupational diseases. Various forms of poisoning, lung and kidney troubles, and even sarcoma have been traced to workshop processes. In 1931 there were 319 cases of silicosis and 785 of fibrosis of the lungs. This

condition is largely due to the failure of the employer to realise his obligation in the matter, ignorance rather than negligence, but, equally disastrous, and is the subject of almost continuous legislation but a lot more can be done by production engineers to avoid accidents and save our workers from their own carelessness and folly.

## Suspicion and Mistrust.

It seems that suspicion and mistrust lurk in the mind of most men to a greater or lesser extent, an idea that under the surface there is a power or force, determined in some way or other in getting the better of him. This attitude of mind is the cause of much trouble and is to be greatly regretted, because, it prevents a proper understanding of many problems. It is present in all classes of employees although the symptoms are not always the same and it makes quite rational individuals behave in an extremely foolish manner at times. It is very difficult to find an adequate explanation for this perverse trait. It may be due to what we call the preservation of the species or perhaps the animal instinct to secure the largest portion, but, whatever the explanation it is very unfortunate that it persists as many of the difficulties we experience are due entirely to this. To some extent, however, we are not free from blame ourselves, we meet artifice with artifice, and trick with trick. We say we believe in putting all the cards on the table but keep one up the sleeve whenever possible. Well, life is getting much too complex for such subterfuges and the sooner we become perfectly honest with each other the better.

## Legislation.

Owing to the diversity of processes and the multiplicity of manufacturing operations, legislation has had to be introduced to control and regulate how, and under, what conditions many of these processes shall be carried out, and to our shame it must be admitted that most of it is due to employers failing to provide adequate safeguards. I say to our shame because in this respect, we, the production engineers, are literally the employers, and as a direct result we have the various factory acts, dealing with these matters, all clear evidence against us. It is however, want of thought rather than want of heart and many modern shops are trying to do better than the strict letter of the law, some even trying to educate their employees to their obligations and their dangers by a series of posters drawing their attention to the risks they run. There is no doubt, however, that the general results of the imposition of these regulations is beneficial to the workers and the nation as a whole, the saving of life and the diminution of the consequences of injuries are in themselves well worth the trouble and expense. We shall be well advised to keep closely in touch with this matter as much more of this sort of legislation is bound to come, however irksome it may

appear at the time, and it has the advantage of compelling those who would not take the necessary precautions to do so.

**Monotony.**

Much use and misuse has been made of this word but in my opinion there is very little real monotony in factory life. We have heard of the soul destroying monotony of attending to machines, the horrors of watching automatics and of performing the same task day after day, driving men to madness or perhaps suicide. I consider there is no truth in such statements, they are the result of over imagination and a desire for journalist effects. We do, however, find lack of interest and this usually arises from some influence outside the occupation. Ill-health, domestic trouble, over confidence, inattention or being temperamentally unfitted for their work are the principal factors in bringing about this condition and to these must be attributed what is known as monotony. It is therefore obvious that we should spare no effort to ensure that interest is maintained so fully that the whole attention is given to the work in hand, at anyrate so far as possible, and in that way disturbing influences may be kept in the background. On the other hand everything in the nature of distractions ought to be equally avoided, the falling of heavy weights, particularly when unexpected, the intermittent passing of materials along a track or vehicles such as electric trucks are all very disturbing particularly where accurate work is being carried on. Undue heat, fumes, dust, and even the proximity of passersby lead to accidents, spoilt work, and dissatisfied workers.

**Female Labour.**

I think perhaps I ought to mention this question because many here to-night have mixed labour in their shops. Most of the points I have dealt with affect equally men and women, there is, however, one noticeable difference between the sexes, women are very much more affected by changes of condition than men, moving them from the control of one foreman to another, moving their machines or work to another part of the shop, any trivial happening of this sort will thoroughly upset them, while changing their work will frequently result in losing them, in this they are quite contrary to boys and youths who continually want changes. In a general way women reach a much more uniform standard of ability, there is not nearly so much variation in performance as men, and the average ability is distinctly higher within their limitations. Very few give any trouble whatever while their natural cleanliness and tidiness is definitely an asset. Whether women ought to be employed in engineering workshops or not has been discussed many times without a satisfactory answer being arrived at, owing, how-

ever, to the steadily increasing proportion of females in our population, it is fairly safe to say that they will continue to be so employed, and in increasing numbers. Personally, I think a very good case could be made out against the prevailing system of indiscriminately mixing males and females, the sex impulse is unduly emphasized, particularly in the adolescent, discipline is more difficult to maintain and many other points arise, but if we have to look forward to increasing numbers of females then segregation cannot be carried out. Care must, of course, be taken to ensure that the work women are expected to perform is suitable for them as they are undoubtedly more susceptible to fatigue and ill-affects from heavy or exacting work, where, however, manipulation and nimbleness of the hands is required particularly when no sort of tool is needed there can be no question that women are in most instances superior to men.

## What of the Future.

What may be done to improve the workman's attitude to his employment? I think the answer to this as well as many other problems that confront the production engineer is training. At present our employees of all grades learn in the old costly school of experience, and while that school will never be closed for want of pupils, if it were possible to impart the knowledge at our disposal to-day to our young employees we could materially reduce the difficulties. It may of course be reasoned that this knowledge represents the whole philosophy of industrial life and can only be properly understood and appreciated by the relatively few who may be able to devote the necessary time and attention to pursue the subject far enough to obtain a comprehensive grasp of its magnitude and importance. If this be true then the problem ought to be taken up by our universities and other centres of learning. It would, however, be of enormous advantage if our young people were taught before they finish their schooling more of the elementary facts concerning industrial economics, the relationship of capital and labour, the causes of unemployment so far as known, the avoidance of accidents, the conditions governing employment, and so on. Knowledge of this sort would be more valuable to the majority of our lads than some they acquire at present. I shall have to differentiate, of course, between the pupils of the secondary and higher grade schools and those who commence work after leaving the elementary schools, and who do not have the same opportunities of receiving such instruction. The situation is really difficult, but obviously vocational training would be much more readily absorbed if some of the whys and wherefores, the inner meaning and importance were understood. It should be remembered that the average elementary school boy starts his working life subject to many

influences, he absorbs dogmas and 'isms as he grows older, he learns lessons which regulate his attitude later in life, frequently to his own detriment, unless he is sufficiently fortunate to come in contact with someone or some influence which causes him of his own volition to ascertain where he stands. Much good would come, I am sure, from any efforts that were made to impart some information to our boys on these matters. It may be necessary to make allowances for the various frailties of human nature in this matter, it may even be that some of the difficulties we experience are due to human nature itself rather than to lack of training or power of observation. Why, for instance, does an operator who, in a general way, is a perfectly good fellow, immediately drop his speed and engage the lowest feed when the rate fixer appears? The fabled ostrich burying its head in the sand is quite sensible by comparison, he, instead of hiding anything makes everything including his own folly obvious. It may be that this is temperamental, the result of the particular quality and composition of the grey matter comprising his brain, or a subconscious part of his make-up compelling him to take every possible precaution for his self-preservation, or even a conscious and deliberate effort to secure the best terms for himself, it may be either of these, but personally, I feel that it is entirely due to an incomplete understanding of what after all are very elementary rules governing such matters.

**Unemployment.**

Unemployment has a direct bearing on our subject, because those who have reasonably continuous employment will have a very different outlook on matters affecting their attitude to their work from those casually or irregularly employed. The fear of losing his job is a very potent factor in regulating a man's conduct and is, of course, at times, unduly emphasized by both employer and employee, it induces a condition of servility and even a cheerful acquiescence to conditions which other circumstances would exclude. It materially affects acquired skill and manipulative dexterity and nothing crushes an ambitious industrious workman more thoroughly and effectively. Periods such as we are now passing through will make the problem of the human factor in industry of considerably greater magnitude when the happy day of prosperity returns, the present represents a temporary set-back in human progress though I like to consider it as just a pause before greater effort. I mentioned at the commencement, man is a reasoning animal, his ability to examine the past and estimate the probabilities of the future are the largest factors contributing to evolution and progress, and unemployment will be solved in the natural order of things, however remote it may appear to be at the moment. How can it be reasoned that our conquest over

uncompromising toil and hard labour, which has brought more leisure and opportunities to develop our finer susceptibilities and characteristics, given us the time to make scientific efforts to human progress, the ability to produce a greater variety of products in abundance, to sail the oceans, span the continents by air and steel rails, and a thousand other things that come readily to mind. How can it be even considered that these are the causes of unemployment ? We all deplore the present conditions, but we shall rise superior to them, just as we shall eliminate occupational diseases, conquer suspicion and mistrust, reduce injuries and accidents in our workshops, improve our working conditions, and make the whole of our working lives happier and more effective, these things will come and with them we shall create more wealth and a better distribution of the good things the world contains. Men will no longer work under conditions that may prejudice their health, and will enter whole-heartedly into every project having for its object the production of more or better work in a given time. Our old slummy factories will disappear and be replaced by light, airy, well ventilated, clean shops probably on the lines of the best examples existing to-day, all these things are just round the corner, but not nearly so far away as present times may lead us to think and when they come they will bring with them a clearer conception of the lines of human progress, better education, not merely in material matters, but a better understanding of life, its possibilities and meaning and how to use it. Recognition of the fact that neither nations nor individuals can live at the expense of other nations or individuals, that freedom from disease, robust health, good houses, proper food, fewer and better children, greater scientific development, further elimination of heavy fatiguing work, more willingness to face facts, greater wisdom and a better understanding of man's duty to man. Then, the whole world will be a happier place to live in, but, one absorbing topic will still remain for discussion, " The human factor in industry."

## Discussion.

Mr. J. A. Hannay (Member of Council), said that Mr. Youngash had given them something to think about which was a departure from those things they usually considered.

During Mr. Youngash's term of office as Section President he knew of no one who had been more whole-heartedly ready to help the Institution. Nothing had been too much trouble for him, and in accomplishing work for the Institution, he had been an outstanding example. The Secretaries could not have had a better President to work with.

Mr. Youngash had remarked, in the first few words of his address on how the Institution had grown. In this connection, Mr. Hannay pointed out that during Mr. Youngash's term in office there had been 250 new members, and of these he was glad to say that Birmingham had had a very good proportion.

Referring to the "rules and regulations" mentioned in the address, it appeared to him that these would have to be continually altered. There was no question about it, as people were being more and more educated, the old rules and regulations did not stand at all, and had to be altered. Looking back, the rules and regulations which used to obtain in engineering shops when he was an apprentice could not be thought of to-day! Improved education had been responsible for that. It had made general conditions, he would say without hesitation, twice as good as they were forty years ago.

Referring to the subject of monotony, this was one of the directions in which the production engineer could do a lot of good. In planning and scheming devices for production, they ought not to forget that in most cases the machines or devices had to be worked by human beings, and that those human beings had brains. In designing, they should always consider that the human brain could do more work than was perhaps imagined. Some machines and fixtures were made in such a way that they did not call for any interest on the part of the operators, who ought to be helped and encouraged to think, and so get real benefit from their minds.

Mr. I. H. Wright said that his name had been mentioned by Mr. Hannay as having voted, in the early days of the Institution, for the principle of having a working President and not an ornamental President. Up to the present, that principle had worked exceedingly well; in fact, it was working better every time they tried it, and in the case of Mr. Youngash, he had filled the specification entirely.

When he had received the synopsis of Mr. Youngash's address, he had thought " where could such a paper be given ; to what body of industrialists ? " and the reply had been " to the production engineers, and nobody else ! " There was no other engineering institution which was interested in the temperament and psychology of the people with whom they dealt to anything like the same extent as was the Institution of Production Engineers.

Mr. Youngash had dealt with his subject very completely. His observations were what one would expect from a philosophical mind. The change which occurred in the mind of a production engineer who had to deal with employees was an entirely new growth at forty compared with what it was at twenty-five. The young man would say " it is forbidden to do so-and-so ; if you do it you will be dismissed." The older man would say " in the interests of public health, you are requested not to do this." That was a rule and regulation which was far more likely to be complied with. At any rate, whether the older man expressed his rules and regulations in that form or not, that was his attitude. He commanded people to do it, but did not want to show them that he was the boss in order to make them do it. That was a principle in dealing with people which was often not exercised as it ought to be.

Speaking about monotony, he had come across a case some few days ago where some girls in an office had been quite cheered up when a bowl of tadpoles was introduced into the office. It provided something in sight which they could take an interest in, and it seemed to him that some cases of monotony could only be cured by giving a person another job altogether. Any person working in any kind of factory ought to be able to find some detail which was of sufficient interest to remove this condition of monotony. As to the difficulties of unemployment, and " What of the future ? " he was not interested in very much of the future, though the young people were. He would say to them that if, when they were Mr. Youngash's age, they had got to be like him, they would have accomplished quite a lot in the course of doing so.

He had great pleasure in seconding the vote of thanks proposed by Mr. Hannay to Mr. Youngash, for his presidential address, and for his services to the Institution during the past two years.

Mr. T. Butler said he was glad the question of monotony had been raised. He thought that, particularly amongst people outside modern works, a wrong impression prevailed. Girls working at most elementary jobs, handling two or three thousand parts per day, just putting them through one simple process, continually told him how interesting it was, and did not want to be put on to more complicated jobs ! Once a job became automatic, so that the girl could chat with her neighbour without interfering with the

quality of the product, generally speaking, she was very much happier. The National Institute of Industrial Psychology had found that monotony occurred where the job hesitated between the purely automatic work and real craftsmanship.

While on the point of craftsmanship, which their President had mentioned also, it seemed to him that one of the major problems which they as production engineers had to overcome was that of holding the interest of the operator. Mr. Hannay had commented on the same point. He knew an instance of a man who worked at the bench as a second-class fitter, doing miscellaneous work, patching things up, and so on. Outside the works, this man was the leading light in a model engineers' club, and had made one or two beautiful model boats, perfect in every detail, which functioned perfectly. How was it that this man should bring his interest to bear on something outside the works, but not on the job on which he depended for his living? That was the problem they were up against.

MR. E. W. FIELD (President-elect), said he had been immensely pleased to hear Mr. Youngash's summary of the progress of the Institution, and he hoped that, with the help of the members, at the end of his own year of office he might look forward to an equal, or even greater increase in membership. Turning to the actual paper, Mr. Youngash had made a statement in the earlier part contrasting factory life of to-day with factory life of years ago. It took one's mind back to one's own experiences in the very early days, and that also brought forward the point which Mr. Youngash had put later in his paper, that was, the boy entering the factory. Here again, Mr. Field said, he was speaking from experience. He could remember very well the freedom he felt when he went into the factory, as compared with what he had had to put up with at school. When he went into the factory, speaking was encouraged, in that a certain number of older men took an interest in him, and started to teach him something about factory life. He well remembered being very frightened that he should be spoken to by one of the foremen, and set about his business. He thought the education of children, when they were getting near the time for leaving school, could be helped if they were allowed to talk more freely. Instead of sitting there, year after year, putting things down on paper, they should get up and discuss them. He was sure the average type of boy who came into the factory would be educated to a far greater extent in this way, than if he simply learned mathematical tables, and formulæ. He did not get sufficient grounding in commonsense applied to meeting and dealing with his fellow-men.

He had been taught to look up to the male teacher of, say, thirty-five years of age, and was rather inclined to think that a wonderful

age, whereas when he got to the factory, and found there men of fifty, instead of listening to them, he was inclined to think them much too old, and knowing far too much to make any contact with.

If those boys were taught to get up in class and express some views themselves, and there was some interchange of ideas, in the later years we should get a very much better type of production engineer. They could not all be production engineers in the sense of the term as they understood it, but every one was potential raw material for them, and it was obvious that they had to pick some of them out, and to enable these to follow in their own footsteps.

It was rather strange that the three previous speakers should have spoken about monotony. In his opinion, monotony was closely bound up with bodily fatigue. It might not be fatigue of the whole body, but in the case of a man doing something with two fingers, for instance, sooner or later those two fingers would get tired. From that point of view a great deal could be done by much shorter shifts on any given operation. For the sake of argument, take a girl on the test bench, gauging ten thousand similar pieces in one day. If she did that from eight o'clock to ten, or from ten o'clock to twelve, and then passed on to another job, probably the monotony might be considerably overcome.

Although it was contrary to what he had just been saying, he quite agreed with Mr. Butler who said those girls were interested in the apparently monotonous work. If quantity was embodied in the day's production, that brought an interest of its own. If one took, for instance, an operator who one day produced 2,000 pieces, the next day 2,050, and after that 1,950, there was a certain interest in his or her ability to maintain a standard or beat that standard.

If, on the other hand, one brought that down to the simple semi-automatic machine which was going to produce a thousand pieces per day that was monotony, and he would suggest in this case a change over of operators. He had seen that done quite recently with great success. On a rather heavy operation, where the operators were given two-hour shifts, and maintaining four operators on an eight-hour day, wonderful production was being secured from a machine tool.

He had been interested to hear Mr. Youngash's suggestion that the machine tool should cause the operator to think. He had always thought that it did!

Mr. Wright had emphasised in his remarks the need for reasonable treatment of operators or employees, and had instanced the young foreman of twenty-five who said, "You have got to do it," and the foreman of forty-five who said, "You might do it." It rather seemed that the younger man showed an iron hand, and the older man an iron hand in a velvet glove! Both secured their object, but he was of the opinion that the suggestion was better than the command.

Contrasting ultra-modern factories, where everything had to be done precisely, and where one wondered now they were able to get employees who could think for themselves, with other factories where the suggestions were made in the interests of the workpeople, he had found from experience that in the latter case the people responded with far greater alacrity, and far greater genuineness, than if one forced them to do anything.

As Mr. Youngash had tried to tell them in his address, the human factor had got brains ; he was the reasoning animal of the whole tribe ; and unless they gave him something to think about they were lacking as production engineers. If they could not give him anything to think about on his actual job, that did not altogether matter if they could give him an interest in his leisure hours. If conditions of work could be made amenable, and the leisure which the man had could be used in a reasonable manner, then the world would be a much better place for everybody, and they should get better production in quality and quantity.

Mr. J. L. Munn observed that apparently getting one's living was rather a serious matter, and Mr. Youngash appeared to have touched on every point affecting it. The question of monotony had been freely ventilated, in many instances wrongly, in his opinion. He gave as an illustration the production of one million electric switches per week, with which he had been concerned just before the war. That, before the war, was a fairly comprehensive production. The lay-out of operations was so well planned and simple, and the mechanical and interested way in which the operators set about this job—the rhythm of it—appeared to him to cut out any possibility of anybody suffering from monotony.

Mr. B. T. Ware said he proposed to leave monotony out of his remarks, as it had been so much discussed, and went on to speak of fatigue. He thought personally that fatigue could be quite easily avoided in a lot of cases, if not always. It seemed to him that operators were having to bend down and pick something up, machine it, and then put it down somewhere else, in some cases, when it ought to have been on the level of the man's hand to start with, and most certainly should not go down to floor level to start this laborious process all over again.

In regard to accidents, Mr. Ware said that a certain amount had been done to prevent them, but not half enough, for the simple reason that operators becoming tired got indifferent and did not take the precautions they normally would do.

In some factories with which he had been connected, a definite "Safety Inspector" was appointed whose definite function was to see that no risks were taken by the men, and that all possible means were used to safeguard both them and the plant generally. The operators more often than not could not help themselves, and the

foremen had not the time, but this Safety Inspector went round looking out all the time for possible causes of danger and having them put right.

MR. T. A. JACOBS said he had been very interested in Mr. Youngash's address.

The monotony of the worker was not caused by doing the same job day after day, but by the conditions under which he had to perform his duties. Taking as an example a man working on piece work, doing the same job day after day, we should not forget the fact that when we engaged a man, a contract had been agreed upon by the workman on the one hand, and by the employer on the other, to sell his labour for a given day rate plus piece work earnings, and it was a natural sequence that any interruption, waiting for work, or tools continually giving way, would lead to the man becoming dissatisfied because of the loss to him.

It should be a workman's privilege to report to his foreman whatever interferes with the efficient working of his job, and the foreman's duty to the man, and to the firm he represented, to see if the interruptions could be remedied.

He would mention, in illustration, details of a works where a department had been partly reorganised for the better handling of work. Two men complained that they could earn very little bonus although they admitted the conditions were better to work under. After considering their complaint, it was found that there were too many operators on the job. Two were transferred to other work, and the cause of the monotony, of not having sufficient work, was cured.

He had been engaged as an investigator in industry for many years, and must confess that he had not heard any workman complain about his work being monotonous. It was generally the conditions and interference with his earnings of which he complained. If it was ensured that the workman, particularly on piece work, had plenty of work, and the conditions were good, there would never be any complaint of monotony. It was a matter of common experience that an intimate relation exists between the conditions surrounding a workman, and his efficiency.

MR. E. P. EDWARDS spoke about suspicion and mistrust, and expressed the opinion that it had been largely engendered by the employers, in which he would include production engineers, as such, in past years. He did not mean the immediate past years, but in a very much earlier period. They all knew that in the engineering industry it used to be almost an unwritten law that no man was allowed to earn more than a certain amount of bonus, usually 25 per cent., by the piece work method on which he might be working. In a factory with which he had been connected some years ago, the management had become a little more enlightened, and although

they were steeped in tradition, had decided to break away from this law of 25 per cent. Those people in the works whose duty it was to interpret these instructions, found very considerable difficulty arising through suspicion, and Mr. Edwards said he felt sure many of the audience would have experienced a similar difficulty in breaking down the wall of mistrust between management and workers, both male and female, and the feeling that this was "only another game." It was not until a considerable time had expired that they really got under way, and at the end of the year in which no alterations had been made in the piece work prices, the production curve suddenly took an upward direction in a very remarkable manner. As soon as the employees really got into their minds what the management meant, the response was wonderful.

While he did not think that to-day that feeling existed in many concerns, he said that where it did, they ought to get rid of it as quickly as possible, and there would be no doubt about the response they would get. Let the people earn what they could. As they all knew, it was on overheads that they saved most money, and in the case under review, the overheads remained almost constant, or rather fell proportionately with the increased output.

Mr. D. A. Tilt referred to distraction, and said that this was not always due to vehicles passing, but sometimes to the heads of the departments, or the management, passing through the shops. He had been told by a commander of a naval department that they had found that if any of the gold-braided men walked through the stokers' department of the ship, the men immediately slacked off, and were too nervous to work. The only way of getting work out of them had been to prohibit as much as possible the gold-braided men from walking about in these departments. He would therefore like to ask Mr. Youngash whether the heads of departments ought to be allowed to walk too freely amongst the men?—(Laughter).

Mr. J. France remarked that quite a lot had been said at various times about the training of the younger engineers, and Mr. Youngash had mentioned several subjects which he thought might be taught to young students before they left school. He might safely say that the Examinations Committee were certainly doing their utmost to bring those subjects into more common use in the technical schools.

Mr. Youngash himself, as a member of the Examinations Committee, was doing his utmost in this direction.

A point to which Mr. Youngash had given a lot of thought, and which he had mentioned in his address, was that of interchanging new ideas and expert opinions with the younger men, quickly. Personally, he did not think this was a task which could be undertaken by a technical school. The reason for this was that they were apt to get out of touch with current practice. To his mind, there was only one place where it could be done, and that was,

obviously, there in their own meetings. They met for the interchange of ideas, they discussed them fully and freely, and it gave the young engineer a chance to get hold of information. A new Graduate Section had been formed, in which they would have an opportunity to speak for themselves, which, as Mr. Field had said, they had little chance of doing elsewhere. Mr. Field had unfortunately missed the graduates' meeting, or he would otherwise not have said what he did about the graduates being frightened of getting up and talking. The graduates had rather put the seniors to shame on that occasion!

As to Mr. Hannay's suggestion that they should make production equipment in such a way that it would require the exercise of more intelligence on the part of the operator, he did not think they dare do this. On the contrary, they spent a tremendous amount of time in making equipment such that the most stupid operator could manage it. He thought that Mr. Wright had supplied quite a good solution in the tadpole suggestion.

With reference to unemployment, it seemed to him that it was purely a question of finance; that it depended entirely upon the medium of exchange. He used that expression deliberately, instead of using the term "money," The medium of exchange was used purely in order to allow goods to be exchanged. The amount of the medium of exchange was based entirely upon the quantity of gold, and that quantity of metal varied very little; actually it must slightly increase. The medium of exchange was necessary to the proper flow of wealth. Nowadays they could produce wealth at an enormous rate, taking wealth as being finished articles, produced from raw materials. It therefore appeared that employment would be very greatly improved if the quantity of the medium of exchange was based, not upon gold, but upon the speed at which wealth could be produced.

Mr. Taylor expressed his pleasure in having the opportunity of hearing such a comprehensive address as that Mr. Youngash had given them. There was one point in it he would particularly like to refer to, and that was the figure of 319 deaths from silicosis during last year. He pointed out that these deaths were due to inhaling free silica which was the chief constituent of natural abrasives such as sandstones. As production engineers they could do quite a lot to help in this matter by using wherever possible artificial abrasives. At a later meeting he might be able to give them some definite data on this subject, but when he mentioned that artificial abrasives contained at most but a fraction of a per cent. of free silica, they would see how satisfactory they were in that direction.

Mr. E. J. Wiley said he could not let the opportunity go by without adding his thanks to those of the previous speakers, for the address Mr. Youngash had given to them, and he looked forward

to seeing it in print at a later date. It contained words of wisdom for them all, and particularly for the graduates.

Mr. Johnson after expressing his appreciation of Mr. Youngash's address, mentioned fatigue, and suggested that those people who worried about the fatigue of others, were those who perhaps would be fatigued, or would find work monotonous, if they themselves were doing it. Probably, however, the operators actually doing the work were not so much concerned about it as those who were talking about it. People working on machines were, in most cases, Mr. Johnson suggested, more or less suited to the type of work they took up. As they all knew, in times of depression, people who were occupied on work for which they were not really suited, must, of necessity, take this work and swallow their feelings of monotony and desire to get into some other line, but in the general way, people were more or less suited to their type of work. We all of us had reasons for grumbling, apart from our work, and he thought that the employers, the production engineer, and coming further down, the foremen, could help very much in trying to see the workman's point of view ; not necessarily to be pally with him, but to realise that he was a human being and had certain feelings and troubles ; and in that way it would very much help both employed and employers themselves.

Mr. W. G. Groocock said that when he first heard that Mr. Youngash had chosen for his address the subject of " The Human Factor in Industry " he knew that they were in for a very interesting address. He knew, further, that whether the subject was touched on lightly or explored deeply all would go away wiser than when they came. He proposed to mention one or two of the points that the President had dealt with, not from the point of view of the critic, but, rather, to amplify such points.

Mr. Youngash had dealt quite fully with the human nature of the operator and his status in the shop. Speaking for himself, he (Mr. Groocock) said that this was not the most troublesome human nature that he had to deal with. He found it much easier to read the mind of both the operator and the foreman than it was to read the minds of the directors. He thought that if we wished to be successful we must pay some attention to these so-called higher mentalities. If we could get a satisfactory grip on the minds of those we came in contact with, we were well on the way to finding a solution to the human problem in management.

Our President has spoken of environment, and in this connection we must always remember that the environment of to-day is not what it was twenty years ago and this was all to the good. We must always be looking forward to see that the conditions of our workers—by this he meant the total force—were always tending to improve. If the working force could be shown that efforts were made to im-

prove their lot then we should have gone a good deal of the way towards cutting out that one thing which every speaker during the evening had seized upon, namely, monotony. The majority of workmen did not complain of monotony, but occasionally one came across people who did and when such cases were explored it would almost invariably be found that it was a case of a square peg in a round hole. In other words, the people who found life monotonous were those who had unsuitable tasks to do or were definitely lazy. For the latter case there was no cure, but for the square peg in the round hole a new job would often provide a cure.

Mr. Youngash had mentioned the economy of high wages. Too often the viewpoint on high wages was wrong. It was not the amount of wages that counted but what could be purchased with those wages, and it was this thought, he believed, that was responsible for the opinion of many who had visited America that although high wages were paid there, the standard of life was not so high as the money earned would seem to indicate that it should be.

As to the question of women in engineering, as we had something over two million surplus women in this country employment must be found for them, and it was being found in many trades that previously women had not entered into. An examination of the returns of workpeople in engineering showed that there was an ever increasing number of women entering employment in our business, and as mechanisation proceeded this number would undoubtedly grow.

On the question of mixing male and female labour, he believed the best results were obtained when one could segregate the sexes. Quite obviously, when segregation took place there was always a certain amount of male labour, particularly in moving material, and nearly always the supervision. He believed, however, that the best results were achieved when segregation was pursued as a policy.

In dealing with the future Mr. Youngash had suggested that boys should be taught something of industrial life before they left school. That was idealistic, but he feared that it was not practicable. His fear was based on the knowledge that teachers at secondary schools did not know life themselves, consequently, being out of touch with industrial life as it existed it would be impossible for them to teach it to others. If such teaching was required it could only be given by forcing teachers into industrial life for a certain section of each year. This would more than likely be a benefit both to the teachers and to the community.

The last point raised by the President which he wished to deal with was the question of unemployment. In general this was an unsatisfactory subject to try and discuss, simply because there was no common basis on which to form our opinions. Unemployment would probably solve itself as and when certain other factors were altered

to bring about world confidence, but there was one side of unemployment that they, as production engineers, might pay some attention to. They all wanted a satisfied force and the only way to get this was to have a stable force. This means that every effort should be made to get an even flow so that there was less of the tendency, which has been so prevalent in the past, of having a whole lot of workpeople in one week and turning them on to the streets the next. If they could stabilise the movements of labour, while it might not have improved the question of unemployment, it would make for a satisfied force in any particular factory.

Mr. Youngash, in replying to the various speakers, thanked the audience for their vote of thanks, and assured them that he had thoroughly enjoyed his two years of office. He said that, in spite of what the committee members had said, he had been very largely a figurehead, but if he had helped any person or the Institution in any way, he felt amply rewarded.

He had been very cautious again this year to select a subject for his address on which, as far as possible, no one could disagree. He did not know by what authority anyone could disagree in public on a presidential address! He had to say, however, that there were in the main very few points on which he could add anything, more than to amplify them to a small extent.

Mr. Hannay had mentioned rules and regulations, and had agreed with him. Obviously rules and regulations must be made. The point that must be emphasised is that they should be framed in such a way that a reasonable person can comply with them without hurting his susceptibilities, or his person, or causing him any feeling of degradation or anything of that nature. If rules did this, it was simply asking the man to disobey. The well-known eighteenth amendment of the laws of the U.S.A. was an example. This legislation was passed, against public opinion, to control the acts of private individuals, and as they all knew, it had lamentably failed.

Mr. Wright had mentioned the suitability of the address. He had deliberately chosen this particular subject. He felt that it was well worth while to deal with some aspect of their life's work—and it was their life's work—that was a little bit out of the ordinary, although actually connected with that work.

Mr. Wright had gone on to mention monotony, and had mentioned in this connection, tadpoles as objects of admiration to assist certain young ladies in their daily tasks. Many things had been tried, gramophones, breaks at certain periods, smoking, and so on. If one took an example like gardening, and considered a man in the midst of a four acre field, people were brave enough to do that sort of thing, and surely there could be no more monotonous occupation than that! This brought into Mr. Youngash's mind a poem called "The Song of

the Plough," in which he remembered that the poet was describing all the wonderful things that he saw whilst following the plough.

The point about it all was that monotony, at any rate so far as engineering work was concerned, as he had mentioned in his address, did not exist. It was merely one of a number of factors, such as low health, domestic trouble, over confidence, inattention, or being temperamentally unfitted for the work, these being the principal factors in bringing about this condition, and he would give this as a reply to all the speakers who had mentioned monotony.

Temperamental unfitness for the job was most frequent, and production engineers ought always to be observing whether the work that the individual was called upon to perform was absorbing his whole attention. If one could not do that, then inattention occurred, and other things would obtrude. For instance, a woman might be thinking about the children she had left at home sitting on the doorstep ; a man might be thinking how he was going to spend his evening. It was due to the fact that his attention had not been wholly absorbed, with the result that his interest was not on the work he was doing. There might be some instances where a short period of comparatively hard work would be the only solution.

Perhaps members would remember a lecture they had a year or two ago, in which an illustration was given of girls cleaning fruit, which was brought into the factory in 28 lb. baskets, and put down in front of the girls on a conveyor at certain intervals. These 28 lb. baskets were so colossal that the girls lost interest. By substituting smaller packages, of two lbs. they got very much better output. This was an instance where they had been able to absorb the attention of the operators. Let us keep them interested by giving small quantities, or doing something which would definitely keep their attention focused on their work.

Mr. Tilt had mentioned outside influences, and Mr. Youngash quite agreed.

The question of being temperamentally unfitted again arose, an instance being the case of the man who was successful in building model steam boats, whereas his normal occupation was performed perfunctorily. There was no doubt the production engineer could do a considerable amount of good by endeavouring to see that individuals were temperamentally fitted for their work. Mr. Tilt had mentioned gold braid, and asked whether higher executives ought to be allowed to walk round amongst the men. They certainly should not—with gold braid on !

Mr. Field had referred to Mr. Wright's remarks about age. He pointed out that he had merely mentioned, as a matter of history and not the year of his birth, that it was in 1844 the first Factory

Act was passed to regulate working conditions. This showed clearly that this problem had always been present.

Mr. Field had mentioned boys entering the factory, and had had something to say about talking. Mr. Youngash observed in parenthesis that he did not believe any person in the world had ever prevented Mr. Field from talking!

Mr. Munn also had mentioned monotony, and emphasised the necessity for maintaining the interest of the worker. Referring to some electric switches, he had said that the whole sequence of operations was so well planned and so rhythmically worked out, that the interest of everyone concerned was maintained. That, of course, was the point he himself had emphasised!

With regard to fatigue, he reasserted that fatigue rarely occurred in engineering shops. Lack of interest was the probable trouble, and whilst they ought to avoid conditions where people had to lift heavy weights (and he heartily agreed with that) in the shops the weights that had to be handled were usually so small that ordinary men could work through a day without undue fatigue being experienced. If there was any heavy lifting to be done, lifting tackle was almost invariably provided.

Mr. Ware had mentioned the question of accidents, and had recommended that a safety official should be appointed. He quite agreed with all that was said on this point. No efforts we might make to prevent accidents could be too great.

Mr. Jacobs again had mentioned monotony, and had expressed the opinion that it arose from bad working conditions. Mr. Youngash agreed on this, and also that working conditions were due to indifferent management. Although his remarks had been intended to deal more particularly with the lower grades of employees, most of it would apply to the higher executives and the higher executives suffered just as much as the lower, due to the working conditions, distraction, etc. Monotony which arose out of bad conditions, however, ought to be much more easily avoided than monotony due to something connected with the operator.

Mr. Edwards had broken away from the usual "monotony" and had mentioned suspicion and mistrust. He was rather surprised that some of the other points had not been mentioned, because after all there were a number of them equally as important as monotony. He begged permission to read the concluding paragraph of his remarks again: "To some extent, however, we are not free from blame ourselves. We meet artifice with artifice and trick with trick. We say we believe in putting all the cards on the table, but keep one up the sleeve whenever possible. Well, life is getting much too complex for such subterfuges, and the sooner we become perfectly honest with each other the better!" This, presumably, was more or less what Mr. Edwards wanted to say.

Mr. France had mentioned training, and Mr. Youngash pointed out that he had rather said "could" than "should." At the same time he would like to emphasise that he was more concerned with the boy who finished his education at the elementary school, and this was the boy they had normally to deal with. If they could teach him something of the elementary rules in industrial life, he would become better than some of the boys now in the shops. In a small way, boys are taught some vocational occupation, a lot of time is spent in teaching the elementary grounding, and he promptly goes off and becomes a milkman, but, whether he becomes a milkman, or eventually arrives in the engineering shop, if he knew some of the conditions which regulate their working lives, it would be very much better, the raw material would be more receptive, and require less of the corners knocked off before attaining an elementary understanding of how and why these things have to be done. Mr. France had gone on to speak about fool-proof equipment. He himself did not see such a lot of fool-proof equipment about.

Whatever the equipment, it must be of such a nature that the interest of the individual was maintained in the work he was doing. It was a difficult problem, and he would not try to minimise it, but the better they could solve it, the higher would be the standard they attained. Mr. France had also discussed the whys and wherefores of unemployment, and the medium of exchange. He proposed to leave it at that.

With regard to Mr. Groocock's remarks, he thought that the problem of unemployment would not solve itself, but would be solved in the natural order of things. He did not see how present conditions could possibly go on, and some sort of solution would appear ; but whether it be through the medium of exchange, or in some other direction, he was not going to prophesy.

Mr. Taylor had mentioned silicosis. He had only used silicosis as an illustration of an occupational disease. The bulk of the deaths from silicosis had, he believed, come from stone quarrying, and that side of engineering, and only a small proportion from the wheel that Mr. Taylor had in mind. He had not specified anything in particular, but had merely used it as an illustration of the direction in which we ought to take precaution. He had mentioned sarcoma in certain parts of the body, which had been prevalent in parts of Lancashire and Yorkshire, and which had been found to be due to the oil from the wool penetrating clothing. By the institution of the simple precaution of frequent changes of clothing, it had been very largely stamped out. It pointed to the necessity for being always on the *qui vive* to anticipate those things which meant serious consequences to our workers.

Mr. Johnson had mentioned fatigue and monotony. There was a difference between fatigue and monotony. Although neither of them

existed, in his interpretation, the lack of interest in a man's employment, as Mr. Johnson had said, was a question of whether he was temperamentally fitted or unfitted for the work he had to do. Also, there was certainly something to be said on the point Mr. Johnson had made about endeavouring to see the worker's point of view. They should try to do that as far as possible, of course.

Mr. Groocock had brought up the point that higher executives were not more immune than works mangers, and lower grades, from these various disadvantages. Mr. Groocock had rather put monotony on a different plane. He said monotony was mental, and with this, he (Mr. Youngash) quite agreed. It was due to the particular job a man was doing, and one of the ways of correcting it, as he had said before, was to create conditions which would absolutely fill all the time spent on the job, and prohibit any share of his attention being devoted to anything other than his work. It might be necessary to make shorter periods in cases where the mental effort was too great, but it was a matter of maintaining this interest in the work.

The question of the economy of high wages had been mentioned, and he had quite expected this to be taken up. Mr. Groocock had confirmed what he had said, that high wages or low wages did not matter in themselves, but it was the standard of living which they enabled the worker to enjoy which mattered. Mr. Groocock had confirmed his remarks about mixed labour, except that he did not agree with mixed labour, while he himself had not said whether he did or did not. He had pointed out that, with the increase in their numbers, women would probably have to be employed in engineering. It would certainly be a better plan to keep them in separate departments when this could be done.

Mr. Groocock had then referred to the few remarks he had made about handing on the knowledge and experience they had to others. If they could do that, and do it effectively, they would confer one of the greatest benefits on the human race which it had ever had. Unfortunately, the young people would not learn lessons except in the costly school of experience. If they would absorb the knowledge which the older ones were able to pass on to them, many of those problems would disappear. Mr. Groocock had then referred to teachers. He had known one instance, at any rate, of a headmaster who spent his holidays, or a large portion of them, in a factory, working as an operator in order to get personal experience, and this man was now head of a training class, teaching engineering in a works with a flourishing apprentice scheme. He gave these boys the necessary lessons in mathematics and allied subjects that the engineering trade demanded, and had for a number of years got quite a large percentage of his boys to pass the Graduate Examination Scheme for the Mechanical Engineers. One saw there the result,

having broken away from purely academical teaching, and coming to a better condition of teaching, closely allied and in touch with everyday life and problems.

# MODERN HEAT TREATMENT.

*Paper presented to the Institution, Luton and Glasgow Sections, by Henry Toplis, A.M.I.Mech.E.*

IN deciding the title of this paper the fact that it was to be given before the Institution of Production Engineers led to the adjective modern before the main title "Heat Treatment." But when the speaker came to analyse the adjective it became immediately obvious that the subject required not one paper but a series of papers, so I must ask your kind indulgence for what after all is a somewhat sketchy discussion of a few points only, leaving, I am afraid, much untouched.

As a separate branch of engineering the scientific study of production is comparatively modern ; and the specific status of the production engineer is a result of the modern tendency towards mass production methods in industry. But whether the status is specific, as in a large works, or taken for granted, as in smaller units, the individual production engineer is vitally interested in all that comes under the heading of heat treatment. Economically, because that affects his costs—in methods, because that affects his output—and in quality because that affects his scrap costs and output efficiency. I use the term " modern " therefore in relation to a few considerations affecting costs, methods, or efficiency.

Old hardening methods were, as a rule, efficient in relation to the job done, even if the hardener was a sort of high priest performing secret rites with the help of redheaded boys and magic powders. Eventually, however, many of these high priests bowed their knees to Mr. Ford, opened their shrine to the production engineer and chemist—sacked their redheaded boys (who of course were totally inadequate as suppliers of quenching oil) and agreed to accept the assistance of pyrometers and modern methods. Others, refusing to bow the knee, were relegated to the tool hardening departments where the human element is a considerable factor, and time at temperature still a matter for individual experience and judgment.

## The Human Element in Heat Treatment.

In the evolution of furnace control we have had pyrometers, recorders, temperature controls, and time switches, all tending to eliminate what is called the human element. But the elimination of the human element actually means the elimination of human effort, and not that of experience and judgment—a distinction often not sufficiently emphasised.

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*Luton, 9th November; Glasgow, 17th November, 1932.*

Experience tells us that our pyrometers may go wrong, our temperature controls may get out of order, and our time switches may become inoperative, so the human element has to re-enter in the checking of our pyrometers as often and as carefully as we do our micrometers and gauges. But having done this, we have still to make sure that the pyrometer registers not only its own temperature but also correctly indicates the temperature of the work—often another matter altogether. So all our instrumental aids must not relieve the furnace operator from his primary duty of visually checking furnace temperature as a regular and necessary routine. For, after all, we should expect the same skilled interest in a furnace as we expect a machinist to show in his machine, and if a temperature variation exists it is there to be remedied, not as an excuse to be utilised in time of trouble. All too often we find a modern machine shop associated with a very out of date hardening department, and a hardener suffering either from an inferiority or persecutory complex; and there is still a subconscious idea prevalent that the installing of a pyrometer will cure old age and senile decay in a twenty year old furnace.

## Pyrometer and Recorder Checking.

Pyrometer manufacturers have a useful routine checking service, but I am convinced that, where such is possible, this service should be amplified by an internal checking system, available as a daily routine, or in cases of doubt or dispute. The necessary apparatus is not unduly expensive and for a base metal installation may consist of: (1) *A Standard Indicator*; (2) *A Millivolt Box*; (3) *A Salt Bath giving the fusion point of common salt.* It is possible by these simple means to check not only the installation as a whole but the component parts of the installation. The salt bath will check the E.M.F. output of the couple at freezing point of the salt. The millivolt box in conjunction with the standard indicator is useful for the routine checking of working temperatures in situ.

## Furnaces and their Working Thermal Efficiency.

The competition between gas, electricity, and oil as heating agents for furnaces has been intensified in the last few years. I do not intend to advocate any one of these in a general sense but rather to deal with the more apparent advantages and disadvantages of each, and then to show a price-working efficiency analysis, which may, perhaps, illustrate the field for development in each instance. We can commence by stating that there are special cases where the advantages of one type are of greater importance than the aspect of strict economy. Such cases you have met and take for granted. Solid fuel furnaces have the advantage of high B.Th.Us. for unit cost, but low thermal efficiency of working, and flue losses are heavy.

Labour charges for fuel storage and transport are high, and these furnaces do not lend themselves to temperature control. Oil fired furnaces have much higher B.Th.Us. for unit cost than gas, but a comparatively low working efficiency, although improved design is increasing this figure. Flue losses are generally heavy. Fuel storage and transport is also a factor, as with solid fuel furnaces.

Gas fired furnaces have a lower fuel value of B.Th.Us. for unit cost, but have no fuel storage or transport factor. The efficiency of old type gas furnaces is low, but is being considerably improved by modern design. Gas fired furnaces are capable of being temperature controlled and the furnace atmosphere is easily manipulated. All furnaces having circulatory flames and gases heat up the work at a quicker rate than electric furnaces where the heat transference is mainly by radiation only. The output per hour, therefore, from gas or oil furnaces is usually greater then than from an electric furnace of equal size—although this is only one factor in the many which determine the overall utility and efficiency of any particular type.

Electric furnaces give the lowest B.Th.Us. for unit cost, but offset against this they usually have the highest thermal efficiency due to low radiation and no flue losses. They are the easiest to maintain in temperature but the furnace atmosphere is not directly controllable, and if reducing conditions are desired, an outside agency such as gas is very often used—either to burn up excess oxygen in the furnace chambers—or alternatively to prevent the access of air into the furnace. In the latter connection it is surprising what a slight temperature gradient at a badly fitting door will do towards setting up a convectional air flow, with, sometimes, really bad oxidising conditions. This is usually most serious when found in a high speed furnace, and the remedy is obvious.

The advent of the electric furnace has spurred the makers of gas and oil furnaces to improved design, and the present position is: "That if users are prepared to pay the same price for a gas furnace as they would have to pay for an equal sized electric furnace the final decision is then largely a matter of the respective costs of fuel in their particular district!" But, as I said before, there are special features in each case which may determine its use apart from actual working costs.

The upkeep costs for repairs vary with the type of furnace—temperature and nature of load. The factors which determine overall furnace efficiency are: (1) *Unit cost of fuel plus storage and transport*; (2) *Thermal efficiency of furnace*; (3) *Capacity of furnace in output per hour*; (4) *Repairs—Upkeep and direct labour charges*; (5) *The adaptability of the furnace to the particular job required*. In this connection I would point out that whilst it is usual in the machine shop to build a machine to the special requirements of particular jobs, furnaces are built mainly for general purposes, and

PRICE: THERMAL EFFICIENCY RATIOS OF VARIOUS FUELS.

| Fuel | Nominal Price | Calorific Value in B.Th.Us. | B.Th.Us. per 1d. at Thermal Efficiency of | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | 20 % | 30 % | 40 % | 50 % | 60 % | 70 % | 80 % | 90 % |
| Coke ... | 30s. per ton | 12,500 per lb. | 15,400 | 23,100 | 30,800 | 38,500 | 46,200 | 53,900 | 61,600 | 69,300 |
| Gas ... | 3s. per 1,000 | 475 per cu. ft. | 2,640 | 3,960 | 5,280 | 6,600 | 7,920 | 9,240 | 10,560 | 11,880 |
| ,, ... | 2s. 6d. ,, | 475 ,, | 3,160 | 4,740 | 6,320 | 7,900 | 9,480 | 11,060 | 12,640 | 14,220 |
| ,, ... | 2s. 0d. ,, | 475 ,, | 3,960 | 5,940 | 7,920 | 9,900 | 11,880 | 13,860 | 15,840 | 17,820 |
| ,, ... | 1s. 6d. ,, | 475 ,, | 5,280 | 7,920 | 10,560 | 13,200 | 15,840 | 18,480 | 21,120 | 23,760 |
| Oil ... | 90s. per ton | 18,830 per lb. | 7,112 | 10,660 | 14,220 | 17,780 | 21,330 | 24,892 | 28,440 | 32,000 |
| Electricity | 1d. per unit | 3,413 per kw. hr. | — | — | — | 1,706 | 2,046 | 2,387 | 2,728 | 3,069 |
| ,, | .75d. ,, | 3,413 ,, | — | — | — | 2,275 | 2,720 | 3,185 | 3,630 | 4,095 |
| ,, | .50d. ,, | 3,413 ,, | — | — | — | 3,412 | 4,092 | 4,774 | 5,456 | 6,138 |

**CHART No. 1**

the possibility of extra efficiency to be obtained by special purpose furnaces is sometimes neglected.

The chart No. 1 illustrates the fuel price and efficiency costs for coke, gas, oil, and electricity, at various values of furnace working efficiency. Electric current at ½d. per unit and 90 per cent. efficiency gives 6,138 B.Th.Us. for 1d. Gas at 2s. 6d. per 1,000 and 40 per cent. efficiency is a little cheaper, as is oil at 20 per cent. efficiency. Electricity at ½d. and 70 per cent. efficiency is about equal to gas at 2s. 6d. and 30 per cent. efficiency.

The working efficiency of electric furnaces at their best is not capable of much further improvement, so economic developments lie mainly in the direction of cheaper current, and, perhaps a cheapening of the furnaces themselves. Gas and oil furnaces, on the other hand, can still be considerably improved in working efficiency as well as in cost of fuel. The situation is therefore very interesting. Electricity, for instance, at ¼d. per unit and gas at 1s. per 1,000 would lead to renewed competition with considerable advantage to the consumer. Oil, in spite of the fuel storage and distribution costs has still a few B.Th.Us. up its sleeve and with improved furnace efficiency, must always be worthy of consideration, but the direct cost of the fuel may be liable to fluctuation for reasons outside our immediate control.

A further possible development is that of high pressure coke oven gas distributed from pit head to large industrial areas—a method which has made considerable progress in Germany. We are happily, therefore, in the position that fuel is still subject to competition and our furnaces still capable of thermal improvement.

## Thermal Efficiency of a Furnace.

Figures quoted for the working efficiency of a furnace are simple in themselves but their practical application is limited to strict comparisons between equal sized furnaces with reasonably equal heating up and maintaining periods.

To bring a composite load such as a carburising heat up to 920°C. requires a theoretical amount of heat based on experimental determination of the specific heat of the load at that temperature. The ideal furnace of 100 per cent. efficiency would therefore take in just that amount of heat and having reached temperature would maintain without loss. In fact, a kind of high temperature " thermos flask ! " This is not possible in our industrial furnaces of to-day, many of which, owing to high flue and radiation losses and uneconomic working have working efficiencies of below 20 per cent. This is bad enough, but we should appreciate what this efficiency value really means in the case of a load combining heating up and maintaining periods. During the heating up period a portion of the heat units supplied go towards the heating up of the charge,

## EFFECT OF HEATING UP AND MAINTAINING PERIODS ON APPARENT THERMAL EFFICIENCY.

TOTAL LOAD IN FURNACE = 2,000 LBS.

| | | Total Gas Cons'ption | B.Th.U's per Lb. of Load | Working Thermal Efficiency |
|---|---|---|---|---|
| Gas consumption to bring up to 920° C. equals 700 cubic feet for three hours | = 2,100 cu. ft. | 2,100 cu. ft. | 498 | 68 per cent. |
| | | | | Per cent. |
| Gas consumption to maintain at 920° C. = 300 cubic feet per hour ... | One hour = 300 | 2,400 | 570 | 60 |
| | Two hours = 600 | 2,700 | 635 | 53.5 |
| | Three ,, = 900 | 3,000 | 710 | 47.9 |
| | Four ,, = 1,200 | 3,300 | 780 | 43.5 |
| | Five ,, = 1,500 | 3,600 | 855 | 40.0 |

CHART No. 2.

but during the maintaining period all the heat supplied can actually be termed inefficiency, for its magnitude depends on heat losses from radiation and flue gases. The chart shows how the figure conventionally termed efficiency is progressively reduced as the maintaining period increases.

Chart No. 3, extracted from figures supplied by Dr. Walter, of Birmingham Industrial Laboratories, gives an analysis of the various losses during heating up and maintaining times respectively.

**Carburising in a Gas Furnace.**

Now let us take a thermal analysis of a week's carburising run on a gas fired furnace. The total heat supplied per lb. of load = 1,530 B.Th.Us. The actual theoretical heat required to bring the load up to 920°C. calculated on the specific heats of steel and compound at 920°C. = 340 B.Th.Us. per lb. of gross load (Dr. Walter—Proceedings Gas Engineers, 1932). Flue losses, radiation losses, and heating up of furnace, therefore account for the difference. The ratio $\frac{340}{1530}$ can serve as an indication of furnace efficiency, but is, of course only comparable between two furnaces with equal loads, and with reasonably equal heating up and maintaining periods. In this instance the ratio, given as a percentage = 22.2 per cent, and the cost per lb. of gross load = .096d. per lb. with gas at 2s. 6d.

**Carburising in an Electric Furnace.**

It is not my desire to come down heavily on the side of any one particular form of furnace such as gas, oil, or electric, and this is not a propagandist lecture.

**Case Hardening.**

In this paper I cannot of course do justice to a subject which would require a complete lecture for adequate treatment, so I must content myself by mentioning a few aspects most likely to interest your members.

**Compounds.**

Compounds are many and varied, and, judging by the makers' catalogues they are all the best, and their penetrations all that the most pessimistic progress man could desire. In composition they may be classified as follows: (1) *Energised wood charcoal mixtures;* (2) *Mixtures containing coke;* (3) *Hydro-carbonated bone;* (4) *Leather, bone, and charcoal mixtures.*

Prices vary, of course, and the user should at least assure himself that he is not paying wood charcoal or bone prices for coke. There may be reasons, apart from economy, why certain mixtures are preferred, but accepting for the moment equal penetrations from

## HEAT BALANCE OF GAS FURNACE.

(Dr. Walter).

| | B.Th.U's | | Heating up Period | B.Th.U's. | | Heating up and Maintaining Period |
|---|---|---|---|---|---|---|
| | | | per cent. | | | per cent. |
| Heat supplied per Lb of Load (Total) ... | 536 | = | 100 | 920 | = | 100 |
| Heat required per Lb. of Load (920° C.) ... | 340 | = | 63.4 | 340 | = | 37 |
| Heat carried away by Flue Products ... | 113.8 | = | 21.2 | 195 | = | 21.2 |
| Heat Lost by Radiation ... ... ... | 82.2 | = | 15.3 | 82.2<br>302 | = | 8.95<br>32.84 |

CHART No. 3.

various compounds, I propose to indicate a scheme by which an economic comparison is possible.

To determine the working costs of a compound we must know the following points: (1) *Is it a shrinking or non-shrinking compound?* (2) *Is it a repeating or non-repeating compound?* (3) *Is it a dusty or graded compound?* (4) *What is its weight per cubic foot?* (5) *What is its price?* (6) *And, of course, its rate of penetration?* (7) *The specific heat and heat conductivity of the compound.*

You will see that the weight per cubic foot varies with different compounds, a matter for consideration as the usage is by volume although the price is by weight. Shrinkage for first heat varies, but after the first heat is not considerable if the compound requires only small additions for repeating. Such additions, of course, depend on the composition of the mixture, and are at a maximum with a wood charcoal mixture with suitable energiser.

These compounds have the highest total carbon content and the energiser ensures the chemical reaction necessary for the formation of carburising gases. To obtain the best results from such a compound the storage of used material should be done in shallow bins giving free access of air, and the working stock taken from a bin which has been standing for some time. The day to day consumption of used material is not economic practice, as the regeneration of the energiser by air contact is not then complete.

**Boxes.**

The size of carburising boxes as well as the material used has considerable effect on the efficiency and cost of the operation. Speaking broadly, box size and shape should be so designed that the work is heated up uniformly and that the temperature lag between outside and centre of the box is as small as possible. With very large boxes and a small grade dusty compound, considerable temperature lag does take place, and if the total time in the box is not long, penetrations may be different in work near the edge and centre of box respectively.

The ratio of work carburised to total weight of load varies enormously, but two examples may help us to appreciate the factors involved—namely, that the net weight of work carburised is usually only a small percentage of the gross total load in the furnace.

Example 1 illustrates a practice where heavy boxes are used and the net load is only 25.5 per cent. of the total. Reducing the box section to 5/16″ the net load is increased to 31 per cent. of the total, with a saving in total weight of 16.7 per cent. and a theoretical thermal saving of 14 per cent.

Chart No. 6 shews the effect of reducing the box section and consequently the gross load of the charge. This reduction in box

## ECONOMIC ANALYSIS OF COMPOUNDS.

| Compound | Weight per Cu. Foot | Shrinkage : First Heat | Dustage : First Heat | Repeating Properties after First Heat Addition Old New | Cost per Cubic Foot. After First Heat Shrinkage | Cost per Cubic Foot. Total Repeating Addition for Ten Heats | Cost per Cubic Foot. Cost per Heat for Eleven Heats |
|---|---|---|---|---|---|---|---|
| | | PER CENT. | PER CENT. | | | | |
| A ... ... | 21 Lbs. | 25 | 2 | 4 to 1 | 45.7d. | 72d. | 10.7d. |
| B ... ... | 31 ,, | 15 | 3 | 3 ,, 1 | 46.0d. | 97.5d. | 13.0d. |
| C ... ... | 41 ,, | 12 | 2 | 2 ,, 1 | 90.0d. | 263.0d. | 32.0d. |
| D ... ... | 26 ,, | 20 | 5 | 2 ,, 1 | 48.75d. | 133d. | 16.5d. |
| E ... ... | 50 ,, | 8 | 1 | 1 ,, 1 | 98.0d. | 450d. | 49.9d. |

CHART No. 4.

weight is a very fruitful field for research for all those interested in lowering the costs of carburising.

The foregoing, of course, applies only to size of box irrespective of the material used, but the growing use of heat resisting alloys is sufficiently important to warrant our attention. It is a fact that boxes in heat-resisting alloys generally hold their shape for a much longer percentage of their total life, than do ordinary welded boiler plate boxes, and for this advantage alone their use can be recommended. But like everything else in these days of economy their use must be justified on the grounds of cost, so we will now analyse the arithmetic of the comparison.

Boiler plate boxes at 2.4d. per lb. have a life varying from 200 hours to 300 hours according to furnace conditions and general usage. So taking an average of 250 hours we find this equals 104 hours per penny per lb. Now alloy boxes vary in price from 30 pence to 45 pence per lb., say an average of 35 pence per lb. These boxes should therefore give $\frac{35}{2.4} = 14.6$ times the life of the boiler plate box, or approximately 3,650 hours, a life obtainable under reasonably good furnace conditions.

But we have been taking equal weights for boiler plate and alloy boxes, a condition only necessary in special conditions, as it is possible by the use of these alloys to reduce box weight considerably. For instance, a boiler plate box $12'' \times 10'' \times 8''$ weighing 72 lbs. can be replaced by a thinner alloy box weighing 56 lbs., a saving in weight of approximately 22 per cent. As a box against box comparison we get the following: 72 lbs. boiler plate at 2.4d per lb. give 250 hours, against which 56 lbs. of alloy box at 35d. per lb. would have to give 2,800 hours to become an economic proposition. At 30d. per lb. the alloy box would have to give 2,400 hours which is well within a specification guarantee of 3,500 hours.

Some present may disagree with the box against box method of comparison, or may, from their own practice, differ from the sample figures I have quoted. For instance, lives on boiler plate boxes can and do reach a higher figure than 250 hours, which of course sets a higher standard on the alloy box comparison; and those who can truthfully claim 450 hours are, of course, giving a very difficult job to the advocates of heat-resisting alloys. On the other hand, however, some users are certainly not obtaining even 200 hours. A further criticism, which has perhaps more foundation, is that of the capital investment involved in a heavy purchase of alloy boxes, and where the works routine does not allow these boxes to be used for more than once or twice weekly. In these cases the spreading over of the investment is the most satisfactory way to build up a stock. The life of alloy boxes is detrimentally influenced by solid fuel, or unscrubbed producer gas containing much sulphur and by

BOXES USED = SIX.

| | $18'' \times 12'' \times 8\frac{1}{2}'' \times \frac{1}{2}''$ (Example I). | | $18'' \times 12'' \times 8\frac{1}{2}'' \times \frac{5}{16}''$ (Alloy) (Example Ia). | |
|---|---|---|---|---|
| | | Per cent. | | Per cent. |
| Weight of Boxes ... ... | 742 Lbs. | = 60.0 | 540 Lbs. | = 52.0 |
| ,, Compound ... ... | 180 ,, | = 14.5 | 180 ,, | = 17.0 |
| ,, Work ... ... ... | 312 ,, | = 25.5 | 312 ,, | = 31.0 |
| Total ... ... ... | 1,234 Lbs. | = 100.0 | 1,032 Lbs. | = 100.0 |
| Thermal Capacity at 920° C.: | | | | |
| Boxes ... ... | 202,566 B.Th.U's. | = 51.0 | 147,420 B.Th.U's. | = 43.5 |
| Compound ... ... | 106,380 ,, | = 27.0 | 106,380 ,, | = 31.0 |
| Work ... ... ... | 85,176 ,, | = 22.0 | 85,176 ,, | = 25.5 |
| Total ... ... ... | 394,122 B.Th.U's. | = 100.0 | 338,976 B.Th.U's. | = 100.0 |

Saving of Total Weight 202 Lbs. = 16.7 per cent. approximately.
,, B.Th.U's. 55,146 ,, = 14.0 ,, ,,

CHART No. 5.

direct impinging oil flames, but these apart, their use can and does lead to increased economy, and cleaner and less slovenly carburising. For who has not seen the bulging abdomen of a middle-aged boiler plate box, and not had trouble from scale—the bane in electric furnace practice ?

## Local protection against Carburising.

If part of a carburised job has to be soft after hardening, the question of the method adopted has to be considered. The alternatives are : (1) *Machining out of the carburised portion before final hardening ;* (2) *Letting down by lead or salt bath after hardening ;* (3) *Prevention of local carburising by clay-proprietary anti-carburiser or coppering.*

The first alternative is fool-proof but sometimes expensive. The second method, that of letting down, is dependent on the skill and judgment of the operator and may, in alloy case hardening steels, lead to temper brittle condition locally, and accidental softening The third method, that of the use of anti-carburisers is perhaps the most popular. The oldest of these methods is to pack part in compound and part in sand or ashes—rather a dirty method—but still used.

For short time carburising on small components coppering is perhaps the most effective method, and where a plating plant exists it is quite economic. It may prove unreliable, however, on long time carburising or where large flat areas require protection, and not all firms have a plating plant. Clay has the drawback that it cracks and is unreliable for really important jobs, but it is used very extensively. The use of borax, salt or similar additions to clay is to be deprecated as fusible slags are formed—sometimes with disastrous results, through " pitting " of the work.

The use of proprietary anti-carburisers is growing and they have an added advantage over copper that they can be left on for the quench and advantage so taken of the delayed quench locally. This is useful when machining has to be done after quenching, for the core hardening of case hardening steels with a little higher carbon than usual may itself render machining difficult unless a delayed quench is possible.

## Quenching from Carburising.

A source of controversy is that connected with the desirability or otherwise of quenching from the box instead of the more usual cooling out process. I cannot say how production engineers are implicated in the controversy, but the progress man is often involved, as he says, with tears in his eyes, that " the so and so's were promised for delivery ten days ago and can't the hardener quench the so and so's from the box ? "

Here again several factors, as intermediate machining operations

| CARBURISING BOXES. | | | | | | |
|---|---|---|---|---|---|---|
| Size of Box | Weight | Weight of Six | Gross Load | Box per Cent. of Gross Load | Saving in Gross Weight | Saving in Gross Weight (approx.) Per Cent. |
| | Lbs. | Lbs. | | Per Cent. | Lbs. | |
| $12'' \times 12'' \times 10'' \times \frac{5}{16}''$ ... ... | 108 | 648 | 1,032 | 62 | | |
| $12'' \times 12'' \times 10'' \times \frac{1}{4}''$ ... ... | 86 | 516 | 900 | 57 | 132 | 12.8 |
| $12'' \times 12'' \times 10'' \times \frac{3}{16}''$ ... ... | 64 | 384 | 768 | 50 | 264 | 25.5 |
| $12'' \times 12'' \times 10'' \times \frac{1}{8}''$ ... ... | 43 | 258 | 642 | 40 | 390 | 38.0 |

CHART No. 6.

or actual inability to quench from the box, have to be taken into consideration. But granted that certain components can, with no difficulty, be efficiently given their first quench from the box, what metallurgical considerations are opposed to the practice? Generally speaking, the opposition is more dogmatic than explanatory, and I shall show on the screen an attempt to compare the properties of box quenched against box cooled and subsequently quenched samples—these being for plain case-hardening steels only. Perhaps, however, I may be forgiven a short discussion at this point on the specification and testing of case-hardened components which, in my opinion, is in rather an unsatisfactory position.

Present methods differentiate between core and case, and test each separately—" core " for physical properties such as tensile strength and impact value—and the " case " for hardness. The difficulties of testing the component as a component have so far been accepted as almost insuperable.

But the component is a composite member and its physical properties are certainly not represented by tests done on its core and case separately. For instance, the core may have a notched impact value of 50 foot lbs. and the component, if such a test were possible, would probably be two or three foot lbs. only. We have in a case-hardened component a high tensile, high elastic case surrounding a lower tensile, more plastic core, and under high stresses there undoubtedly comes a point when the core no longer supports the case, and cracking of the latter takes place.

Any test, therefore, which has for its desideratum the determining of this cracking point is likely to prove of value, especially if the type of stress applied to the component bears some relation to that found in actual use.

As an example of the necessity for practical tests I will quote one instance out of several in my own experience. Certain rollers used in motor cycle and heavy roller chains suffered some years ago an increase of breakage in use—due to the heavier mechanical duty brought about by higher engine power and increased speeds. The routine test on these rollers was, at that time, a drop hammer, and the components had to distort under the drop without breakage. In other words, the typical structure brought about by double quenching was considered ideal for the purpose and a high impact value core was taken for granted. The position, however, grew more serious and something had to be done. Rollers from various treatments were tested and it was found that the then ideal treatment was almost the worst possible, and that a roller previously considered brittle was really a better job. The final treatment adopted was to quench from carburising into water, with no second quench, but followed in some components by a low temperature tempering at 160°C.

Such rollers are actually very brittle under a drop hammer, and the core notched impact value is almost at a minimum, but they do the job. The reason is that the single quench into water gives a low carbon martensite structure with the highest possible compression strength of the core, and so supports the case against compression stresses. A soft core, on the other hand, distorts plastically and leaves the case unsupported and early fracture takes place. I mention this instance—one amongst many—to illustrate the necessity for test conditions to bear some relation to working stresses. As a matter of fact the physical test found, in that instance, most nearly to agree with actual practice, was a static compression test in which the point of first cracking of the case was determined.

In connection with notched impact values I give a tabulation illustrating the relation between this value and structure, bearing in mind that with plain carbon case hardening steels, the latter is largely a function of mass as well as treatment, and that structures obtained on small sections are often quite unobtainable in large sections.

## The Effect of Structure on Impact Value.

The tests were done on a .16 per cent. carbon .57 Mn case hardening steel treated in a diameter of .57 inch and subsequently machined into notched impact test pieces :

| *Condition on Treatment.* | *Impact Value.* |
|---|---|
| Cold drawn condition ... ... ...= | 53 ft. lbs. |
| Heated for one hour at 920°C. and cooled out= | 78 ft. lbs. |
| Water quenched from 920°C. (low carbon martensite) ... ... ... ... ...= | 9 ft. lbs. |
| Oil quenched from 920°C. (a more transitional structure) ... ... ... ... ...= | 22 ft. lbs. |
| Double water quenched from 920°C. and 780°C. ... ... ... ... ...= | 28 ft. lbs. |
| Water quenched from 780°C. only—after cooling out from 920°C. (martensite in ferrite) ... ... ... ... ...= | 6 ft. lbs. |

This latter structure is particularly unsatisfactory, but is only found in those thin sections which will quench the pearlite into high carbon martensite locally—it is in effect, a martensite in ferrite structure. In large sections a more transitional structure is obtained and the impact value goes up.

The foregoing shows the effect of treatment on the core only ; but, I am, through the courtesy of Mr. Page, able to quote a series of figures shewing tests done on test pieces .45 inch diameter, prepared from $\frac{3}{4}$ inch bar which had been carburised for three hours at 900°C. giving a case depth of 20/1000 inch and which were then

given various after treatments. These test pieces were subjected to impact in an un-notched condition, and therefore represent an attempt to test the toughness of the carburised specimen as a complete unit.

| Treatment. | | Un-notched Impact Value. |
|---|---|---|
| First Quench. | Second Quench. | Mean Value. |
| Oil 900°C. | Water 780°C. | 17 ft. lbs. |
| Water 900°C. | Water 780°C. | 29.5 ft. lbs. |
| Oil 900°C. | Oil 780°C. | 83 ft. lbs. |
| Water 900°C. | Oil 780°C. | 95 ft. lbs. |
| Water 900°C. | Nil. | 34.5 ft. lbs. |
| Oil 900°C. | Nil. | 88 ft. lbs. |
| Cool out. | Water 780°C. | 7 ft. lbs. (martensite in ferrite structure) |
| Cool out. | Oil 780°C. | 11 ft. lbs. |

Comparing the results of the previous core tests with those of the carburised test pieces, the feature at once apparent is that the martensite in ferrite structure is again particularly bad—giving only 7 ft. lbs., a very similar result to the 6 ft. lbs. of the notched bar core test with similar structure. It will be seen also that whilst there can be no definite numerical relation between the un-notched and notched tests they follow similar gradients. Mr. Page has, however, carried the investigation further, into a consideration of the effects of cooling or quenching from the box, followed by varying quenchings, and I have put these results into chart form.

## Box Quenching.

It will be seen that cooling from the box gives slightly higher results than is obtained by quenching from the box, final quenches in each case being identical. The magnitude of this increase is, however, not large, being on six treatments an average of 58 ft. lbs. against 49 ft. lbs. or leaving out the single oil quench, and taking five treatments only we have 48 ft. lbs. against 46 ft. lbs.

Regarding the effect of box quenching, Mr. Harrison, of The Daimler Co. Ltd., very kindly gave me the results of an independent test on box quenched and box cooled specimens 7/16 inch diameter—carburised for 5½ hours at 900-910°C.—and given a double water quench in each instance. The case depth was approximately

Such rollers are actually very brittle under a drop hammer, and the core notched impact value is almost at a minimum, but they do the job. The reason is that the single quench into water gives a low carbon martensite structure with the highest possible compression strength of the core, and so supports the case against compression stresses. A soft core, on the other hand, distorts plastically and leaves the case unsupported and early fracture takes place. I mention this instance—one amongst many—to illustrate the necessity for test conditions to bear some relation to working stresses. As a matter of fact the physical test found, in that instance, most nearly to agree with actual practice, was a static compression test in which the point of first cracking of the case was determined.

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| Double water quenched from 920°C. and 780°C. ... ... ... ... ...= | 28 ft. lbs. |
| Water quenched from 780°C. only—after cooling out from 920°C. (martensite in ferrite) ... ... ... ... ...= | 6 ft. lbs. |

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| Water 900°C. | Oil 780°C. | 95 ft. lbs. |
| Water 900°C. | Nil. | 34.5 ft. lbs. |
| Oil 900°C. | Nil. | 88 ft. lbs. |
| Cool out. | Water 780°C. | 7 ft. lbs. (martensite in ferrite structure) |
| Cool out. | Oil 780°C. | 11 ft. lbs. |

Comparing the results of the previous core tests with those of the carburised test pieces, the feature at once apparent is that the martensite in ferrite structure is again particularly bad—giving only 7 ft. lbs., a very similar result to the 6 ft. lbs. of the notched bar core test with similar structure. It will be seen also that whilst there can be no definite numerical relation between the un-notched and notched tests they follow similar gradients. Mr. Page has, however, carried the investigation further, into a consideration of the effects of cooling or quenching from the box, followed by varying quenchings, and I have put these results into chart form.

## Box Quenching.

It will be seen that cooling from the box gives slightly higher results than is obtained by quenching from the box, final quenches in each case being identical. The magnitude of this increase is, however, not large, being on six treatments an average of 58 ft. lbs. against 49 ft. lbs. or leaving out the single oil quench, and taking five treatments only we have 48 ft. lbs. against 46 ft. lbs.

Regarding the effect of box quenching, Mr. Harrison, of The Daimler Co. Ltd., very kindly gave me the results of an independent test on box quenched and box cooled specimens 7/16 inch diameter—carburised for 5½ hours at 900-910°C.—and given a double water quench in each instance. The case depth was approximately

35/1000 inch. The first quenching temperatures being either from box temp. or 900°C.—followed by 765° for the lower quench in each instance. Test pieces were given impact blow in the unnotched-condition and with the case intact. The average of seven box quenched specimens was 23 ft. lbs. and the six box cooled specimens also gave 23 ft. lbs. It would appear, therefore, so far as the significance of these and the previous tests go, that quenching from the box is quite permissible for short time carburising. Free

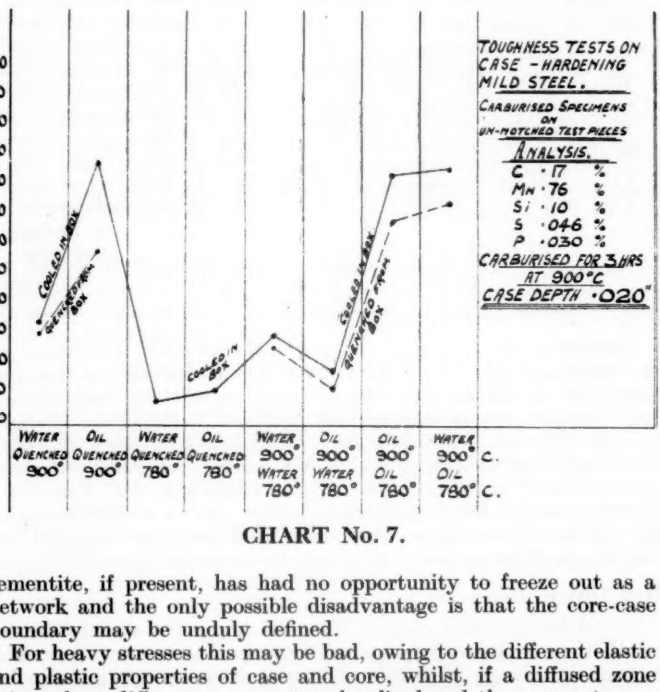


**CHART No. 7.**

cementite, if present, has had no opportunity to freeze out as a network and the only possible disadvantage is that the core-case boundary may be unduly defined.

For heavy stresses this may be bad, owing to the different elastic and plastic properties of case and core, whilst, if a diffused zone exists, these differences are not so localised and the zone acts as a stress gradient. But this apart, there are a large number of components where box quenching is not only permissible but quite satisfactory, and the tests I have quoted may to some extent reassure those who look upon the practice as not permissible under any circumstances. The operation is rather messy, however, and temperature may be lost if conducted in a leisurely manner and in consequence a faulty or ineffective quench results.

From rotary furnaces and cyanide pots quenching direct from carburising is usual, the operation being carried out with less delay and more efficiently than is possible from ordinary box carburising. Quoting from Moore & Ableman, A.S.H.T., March 1928, it is suggested that specimens quenched in oil from box show an increase in fatigue strength over similar specimens cooled in box.

## Carburising Temperatures.

Box carburising is being carried on at temperatures varying from 820°C. to 1000°C., the usual treatment being 900°C. to 920°C.—or a little lower with alloy case hardening steels. Lower temperatures of 820°C. are usual for small components with thin case, where higher temperatures would make it difficult to obtain regular penetrations on work at the outside and centre portions of the box respectively. These temperatures are also used for the carburising of dies or tools where distortion is a serious factor and must be avoided at all costs. The higher temperatures of 950°C. and upwards, where used, are for two separate and not necessarily connected reasons.

Firstly, for the purpose of increased output, and secondly, for the increased carbon content of the case so obtained and consequently increased wearing properties. This practice is controversial and certainly not without dangers, but when done by firms of repute it cannot be dismissed without consideration. One firm uses high temperature carburising for gudgeon pins only, followed by a reheat to 940°C.—air cooled, and subsequently by the usual two reheats and quenches. They consider that the results justify the treatment.

The dangers consequent on a coarse network of free cementite are well-known to produce flaking and an increased tendency to grinding cracks, and high carburising temperatures and slow cooling from carburising both favour the growth of this network. The ordinary reheat to 900°C.-920°C. may not be high enough to break down such a structure formed by carburising at 950°C. or upwards, and the additional process of an air quench from 940°C. does tend somewhat to remedy this undesirable condition.

A prolonged diffusion at a lower temperature will also serve the same purpose and is perhaps the most satisfactory, although the cost is of course much greater. In the case of long time carburising for very heavy components, however, this diffusion treatment may be a negligible portion of the total time and consequently can be quite justified on a cost basis.

## Quenching Media.

Efficient cooling of all quenching tanks is most necessary. The cooling effect of water falls off very rapidly as the temperature of

the bath increases, and, with continuous quenching into an uncooled tank, there is considerable danger of overheating and inefficient quench. The cooling of a water tank is at least as important as that of an oil tank.

A good quenching oil, whilst it has smaller quenching capacity than water has a much flatter curve as the temperature increases, and in fact, little falling off occurs up to 150°F. But here, again cooling is advisable, as, owing to the lower specific heat of oil, the temperature of the bath will be higher than a water tank and whilst the best quenching oils have a flash point of 200°C. it is best not to risk the danger of fire.

The individual quenching of components such as shafts and gears etc., should not cause much trouble, but the bulk quenching of small parts may sometimes be accompanied by softness due to bunching together at the bottom of the tank. I need not emphasize that quenching tanks should be as near to the furnace as possible.

Some time ago I came across a firm who have to reheat to 800°C.-810°C. for the second dip, as their tanks are so far away from the furnaces, that considerable temperature drop takes place en route. I welcome the recent designs where components may be pushed direct into the quenching tank through an orifice in the furnace, without coming into contact with the outside atmosphere. I need not emphasize the necessity for keeping the components as clean as possible and free from scale during reheats—it being a common practice in first class work to sand blast between first and second heats, or even to do a preliminary grinding operation.

In this connection, I came across an amusing episode some time ago. A firm were in bad trouble with soft spots on nickel chrome case hardened shafts, I suggested that more attention should be paid to furnace atmosphere during reheating, but the trouble persisted, until one day the works manager rang me up to say all was lovely once more—the trouble was over—and it was all due to a wonderful liquid his new hardener (he changed them fairly often) had brought along. During the reheat the components were dipped into this solution and replaced in the furnace. As a great favour I was given the formula : *Water, so much ; nitric acid, so much ; tincture of steel, half gill ; tincture of calumba, half gill.* In effect, a pickling bath, but the tinctures of steel and calumba worried me, so I asked my pet druggist, " Well, well," he said, " I have not sold any of that for a long time," " What is it ? " I asked. " Oh, a sort of tonic for men," he replied.

## Volume Changes and Distortion.

The gradual reduction of machining allowances—a source of pride in the production engineer—has been a cause of trouble in the hardening department. In spite of well-known operations such

as previous normalising or intermediate annealing, distortion and volume changes after treatment are still responsibile for much worry and anxiety. And the trouble is that the symptoms are by no means regular. Gauges previously tight suddenly become sloppy and everyone swears that nothing has been changed. Several factors are usually altered frantically and after a period of excitement the job suddenly cures itself, and as something else has in the meanwhile gone wrong we leave the matter alone until it crops up again in two years' time. It is a complex problem and each component has to be studied as a component. Condition of the steel, machining stresses, design, mass, case depth, rate and method of quench, are all factors, and of these, design and mass are only really constant for a given component, the others being at any rate potentially variable.

There is a considerable amount of unrectifiable scrap from this cause and if your society could arrange an evening's discussion on this problem alone the result would be well worth while. I would wish to be present, as a listener. In the meanwhile, however, I would urge the necessity for the keeping of records on all matters connected with this problem. Such records would go far to remove the doubt that these troubles vary directly with the concentration strength of the inspection department.

## The Rotary Furnace.

Rotary carburising is not new and has been used for many years either in conjunction with solid or gas carburisers. With the latter process the gas has to be cracked either by temperature alone or by the addition of a cracking agent such as ammonia. This latter forms the basis of the Schutte furnace—a German process lately seen in this country.

Carburising direct from town's gas is not practicable in England, but I have personal knowledge of one plant using a combination of solid carburiser with town's gas where an output of five cwts. per 2½ hours with a case depth of 1/32 inch is obtained. The consumption of compound is very small. The general practice of rotary carburising, however, entails a consumption of approximately 15 lbs. of compound per 100 lbs. of work. The main advantage lies in the time gained by recharging each heat into an already heated retort.

Within ordinary limits quenching from carburising is safely and easily performed—to be followed by requenching from 760°C. if so desired. It is particularly suited to small components, but owing to the limited size of the usual retort cannot compete against pack hardening for more bulky components. Where the heating up period is a large proportion of total time—as with all small components—rotary carburising may be a real economy.

## The Nitriding Process.

As I have little personal experience with the nitriding process I cannot say much about it. The treatment is a long one if deep penetration is desired, and special steels are necessary. It seems to be successful for those components where intense surface hardness is required together with stability of that hardness at elevated working temperatures.

## Flame Hardening.

The local hardening by flame of components such as the teeth of large gears appears to be making progress and is giving satisfaction for heavy duty gears used in mining engineering. The method. whilst not new, is worked by a proprietary process of which I have no practical knowledge. The flame hardening of valve stem tips is much practised, however, and I have recently come across an instance where the flame hardening locally of the teeth of a small gear wheel has been successfully carried out on a three per cent. nickel, 0.6 per cent. chromium steel. An air blast is used as a quenching medium in this instance and distortion which would otherwise be fatal, is practically negligible.

## Low Temperature Tempering.

All heat-treated components are benefitted by a low temperature tempering at 150-170°C., especially case hardened articles. This temperature, of course, must be below that at which skin softness takes place. The treatment relieves stresses which might otherwise be released during work, with subsequent distortion of cracking.

It is also of decided advantage as an operation prior to grinding, and helps to prevent grinding cracks—providing, of course, that the primary causes of free cementite and actual faulty grinding are absent. It may be considered a fundamental of heat treatment that a tempering operation should be given to all components likely to be subjected to heat during service. Such tempering where possible should be at a temperature slightly higher than that actually obtained in use. Low temperature tempering of cold worked steels has a considerable effect on the physical properties of the material and up to 400°C. the apparent elastic limit is raised considerably. Up to 200°C. both yield point and maximum stress are increased, falling gradually with increasing temperature. Bend tests, however, are not improved by low temperature tempering, and there is a definitely blue brittle range which can occasionally cause serious trouble.

Certain cycle brake levers were rivetted on to the push rod. In this state they were satisfactory, but after enamelling they were absolutely brittle, the rivetted end falling off at very slight stresses. Tempering at 450°C. outside the brittle range before the enamelling

process cured the trouble by reducing the cold work effect. This blue brittle range is also found on heavily cold worked components which are subsequently spot welded—the brittle portion being approximately at the section away from the weld where temperature creep is within the danger range of 250°C. to 350°C.

Whilst not coming within the scope of low temperature tempering a structural condition produced by low temperature annealing is of interest. Cold drawn low carbon steels are sometimes given an annealing at 650° to 670°C. between passes, as the structure so produced is favourable to the cold drawing process. Unfortunately however, it gives bad machining properties and can very adversely affect the cycle time of automatic machine processes. The structural condition produced by this low temperature annealing following cold work is as follows : in its worst state the pearlite is globularised into balls of cementite and grain size is increased. The result is therefore a large grain, soft, ferrite mass, containing these specks of very hard cementite, as opposed to the normalised structure produced at 900°C., in which we have uniformly distributed ferrite and pearlite—a more averaged structure when considered from a machining point of view. Ordinary inspection tests usually fail to indicate the presence of this structure and the microscope is the only reliable and ready method.

## Salt Baths.

Liquid salt baths working at temperatures from 160°C. to 1350°C. are now available. For the treatment of high speed steel the salts are resistance heated directly in a refractory container having two or more electrodes. This type of furnace works on A.C. current at a low voltage, high amperage, with a bath of barium chloride or other suitable salt. The salt seeps into the brickwork for a certain distance and then freezes, forming an efficient non-leaking container with a life of approximately five or six months. Temperatures of 1380°C. are easily obtained and maintained, although the radiation losses from the surface of the salt are heavy. This method lends itself very efficiently to accurate treatment control. The temperature factor is constant, so the only variable, that of time, is determinable for various components.

## Reheating in Salts.

The reheating of tools or components at temperatures of 750°C. to 900°C. in salt baths is every-day practice, the main difficulty being either a slight decarburisation where non-cyanide salts are used, or undesirable carburisation with cyanide salts. Both these factors are, however, dependent on the mass of the job, temperature, and time of immersion, and with care can be rendered negligible if the limitations of the process are appreciated and only jobs suited to the process are treated.

## Cyanide Hardening.

The interesting revival of cyanide hardening and reheating has perhaps done more than anything else to slow up the development of the rotary furnace. Cyanide hardening, is of course, no new process, as it forms the basis of most of the skin compounds which have been and are still used extensively.

## Skin Compound Practice.

To illustrate a method in use for skin hardening, a typical case is where the components are laid side by side and covered locally

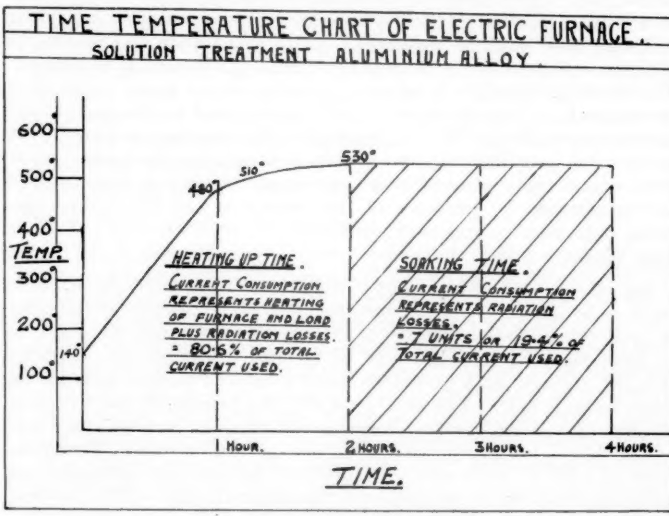


CHART No. 8.

with the skin compound at the portion where carburising is required. The tray is heated in a furnace for about twenty minutes and the components then quenched. This method is, of course, much more efficient than the old dipping process beloved by the blacksmith and the country garage.

Cyanide treatment proper, however, is done in a liquid bath and its use appears to be growing rapidly. Here again it is well to appreciate the limitations of the process, for within those limits it is an exceedingly valuable adjunct to any hardening department. Large mass production components with deep case depth can be

treated in a cyanide bath, but if a regular output is desired it is not then a commercial or economic proposition owing to the limited capacity of a single bath.

It should also be emphasized that the use of a cyanide bath does not render the fundamentals of heat treatment unnecessary. Where the qualities of double quenching are desired—double quenching must be given—and temperature control is equally important.

Carburising temperatures vary considerably according to the routine found most satisfactory. It is, sometimes, however, not easy to obtain a satisfactory core structure with low carbon steels, and low carburising temperatures. If it is desired to keep to the latter practice, a preliminary core refining at 900°C.-920°C. is useful, followed by carburising and quenching and reheating to 760°C. if necessary. The mass of the job—time in bath—and above all the inspection specification the job has to meet will all determine the particular after treatment adopted. The main value of the process is found in the carburising of small and medium-sized components—either of a strictly routine nature such as cycle components—or of a non-routine nature which does not easily fit in with pack hardening practice.

It lends itself well to selective carburising where only a part of the job is immersed. If portions are to be left soft and total immersion is essential then either coppering or the use of an anti-carburiser is necessary, but the coppering must be skilfully applied and to a greater depth than is usual in pack hardening. With an anti-carburiser advantage can be taken of the delayed quench of the protected portion. The use of a protecting flux on the bath such as boric acid and graphite is recommended not only to keep down volatilization, but also to reduce decomposition of the cyanide by air contact.

## A Cyanide Bath as a Reheating Agent.

The use of low grade cyanide baths as reheating agents not only for carburised jobs, but also for non-carburised alloy steels, is growing considerably, and is, in fact, essential in many American and continental specifications. The advantages of freedom from scaling, oxidation, and soft spots are obvious and the extra skin hardness given to non-carburised steels is apparently found useful.

## Cyanide Pots.

The salt container is perhaps the only remaining feature of the process which is hardly satisfactory. This appears to be due to the fact that the materials which have the best resistance to salt attack are only slightly resistant to flame attack, and vice versa. An ordinary pressed steel pot is a suitable compromise for whilst its life is low its replacement cost is also low. Heat resistant alloys

on the other hand whilst eminently suitable for pack hardening are unreliable as high temperature salt containers and the replacement cost in the event of early failure, is very high.

Much can be done, and I think much remains to be done by attention to furnace design, as the cutting action of a blast flame is usually the main cause of failure. The operator, by intelligent observation of the furnace can usually determine when slight leakage is taking place, as this is indicated by the presence of white fumes from the combustion chamber. Cooling down and removal of the pot at this point prevents a nasty mess and much excavation of brickwork. This can be further prevented by a thick layer of sand on the floor of the combustion chamber and easy access should also be given for the purpose of cleaning out the chamber.

## Cyanide Carburising of Small Parts.

| | | | | |
|---|---|---|---|---|
| Output per pot | = | 7 tons | = | 15,680 lbs. |
| Case depth | = | .005″ | | |
| Time per heat | = | 10 mins. | | |
| Temperature | = | 950°C. | | |
| Cyanide used | = | 4½ cwt. | = | .258d. per lb. |
| Oil used | = | 2 tons | = | .121d. ,, ,, |
| Pot cost | = | £5 | = | .077d. ,, ,, |
| Total cost per lb. carburised | | | = | .456d. ,, ,, |

## The Heat Treatment of Aluminium Alloys.

The growing use of heat treatable aluminium alloy castings, especially those in die or chill cast form, has led to the trial of various methods of heating in the search for efficiency with economy. So far as castings are concerned the two temperatures most usually required are approximately 500°C. for the solution treatment, and approximately 150°C.-180°C. for the precipitation treatment. These are temperatures where visual observation is impossible and as the temperature limits are rather critical, a well controlled and regular source of heat is essential. The solution temperature of 500°C. is best obtained in a salt bath or electric furnace. The salt bath is perhaps the most economical and efficient for small and medium sized castings, and the electric furnace for larger and more bulky components. The electric furnace should, however, be fitted with fan or other circulatory method to ensure even temperature.

## Precipitation Treatment of Aluminium Alloys.

This treatment is being performed in temperature controlled electric furnaces, steam chambers, superheated air circulation

chambers, core drying type oven, salt baths. All these, except the steam, leave the job clean and bright—the steam giving a blackened surface considered undesirable in some quarters. The steam process lends itself to large units with heavy overall loads, but when temperatures of over 150°C. are required, steam pressures and superheating problems become serious. Superheated air circulatory chambers are being successfully used, mainly for large size castings. The air is heated by means of an electrical resistance unit and is then circulated as a closed system by means of a fan. The core drying type of oven is also used in conjunction with thermostatic control.

The temperature controlled electric furnace has obvious advantages, although it is not easy to design a large chamber to give uniform regularity throughout at such low temperatures, except by the addition of a circulatory fan.

The salt bath appears to offer a good all-round compromise—at any rate for small components. Overall time is reduced and the temperature is reasonably well maintained within working limits. For the 180°C. treatment it is necessary to use a salt with the lowest possible freezing point, usually 135°C., and although the superheat above fusion point is not large, salt losses will not be heavy as draining can be more prolonged at the precipitation treatment, than with the solution treatment where immediate quenching is required. For the solution treatment a salt fusing at 175°C. or upwards is advisable, and this can be used up to 500°C.-520°C. without decomposition. Some salts containing chlorides have a deleterious attack on light alloys and are accordingly unsuitable.

The solution temperature must be accurately controlled as the tolerance between correct treatment and overheating is small. Such overheating may cause mechanical collapse of the casting in the bath or furnace, or partial fusion. Quenching is commonly performed into boiling water or oil. With water the shock of steam generation may cause mechanical distortion if care is not taken and pockets of undrained salt are a troublesome matter.

For pistons, quenching must be done skirt downwards, as drainage is otherwise impossible. Unfortunately, however, this means the cooling of the thinnest section first and quenching stresses are unavoidable. Oil quenching following salt bath treatment is rather messy as it entails a further removal of the salt.

### Centralisation or Decentralisation.

And now, before I close, just a word about a question which is coming into prominence with the building of large self-contained manufacturing plants, namely, the centralisation or decentralisation of the hardening processes? The production engineer is vitally interested but would not I think make the matter a question

**SOLUTION TREATMENT OF ALUMINIUM ALLOY AT 500°–520° C.**

| | Salt Bath, Furnace Oil Fired. 30 Heats. | Electric Furnace. 30 Heats. |
|---|---|---|
| Weight of Work ... ... ... | 3,600 Lbs. | 3,150 Lbs. |
| Total Time of Treatment ... | 60 Hours. | 90 Hours. |
| Fuel used ... ... ... ... | 120 Galls Oil | 1,200 Units |
| Salt Usage... ... ... ... | 28 Lbs. | |
| Cost per Lb. of Metal Treated | Oil = 468d.<br>Salt = 175d.<br>Total 643d.<br>= .18d. per lb. | 1,200 units at .6d. = 720d.<br>= .23d. per lb. |

**CHART No. 9.**

of generalisation. Cyanide and other salt bath furnaces lend themselves easily to incorporation along the line of production and with regular and continued output decentralisation is called for. Intermediate annealing and normalising should also, where possible, form part of a line of production. Long time box carburising is, however, a different matter altogether and I see no advantage from decentralisation in this type of treatment.

Treatment costs depend largely on the economic use of furnace plant and large general purpose furnaces are usually put to better advantage in a centralised department. Decentralised plant along lines of production should in all cases be specially designed in reference to the special requirements of the job, in exactly the same way that machine tools are designed to specific requirements.

In closing, I would like to acknowledge the facilities given me by Messrs. Kasenit, Ltd., Mr. Whyte and Mr. Ratcliffe, of that firm ; Dr. Walter, of the City Industrial Laboratories, Birmingham, and Mr. Page and Mr. Harrison, for the use of data ; and Mr. R. R. Blight for assistance in the preparation of charts, etc.

## Discussion, Luton Section.

MR. TINKER: I congratulate Mr. Toplis on this very interesting paper. He certainly has had great experience and it has been a pleasure listening to him. The most modern furnaces are the electric furnaces. He showed us the chart of B.T.U. comparisons and of the thermal efficiency percentages. On a normal supply, say, 2s. 6d. per thousand cubic feet of gas and ¾d. per unit of electricity, the electric furnace shows a comparable efficiency. Taking everything into account, however, including labour cost and advantages of cleanliness, etc., probably there is not much in it. In some cases electric furnaces are the better proposition. Referring to Mr. Toplis's remarks that gas furnaces heat up quicker than electric, I do not agree that this is necessarily the case. Regarding carburising, we have now developed a recuperative type of electric furnace, which has proved to be very much cheaper owing to a much higher thermal efficiency. The cost for carburising with a recuperative type electric furnace is .04 to .05 pence per gross lb. treated against .09 pence per gross lb. for the non-recuperative furnace. With regard to boxes, there are a number now being used which are only ⅛ inch thick, made up of fabricated nickel-chromium sheet, and these very quickly repay themselves, taking far less time and fuel to heat up.

MR. TOPLIS: Mr. Tinker obviously has tried to be impartial. Referring to the recuperative electric type of furnace, I hope to have the occasion of hearing more about this. His statement that the ⅛ inch thick fabricated boxes have been on the market is correct. The makers and users have not had sufficient experience yet to know just how they are going to behave. The chief difficulties are due to distortion with hand loading, so mechanical charging is necessary.

MR. GILBERT (Member of Council): With regard to mild steel material for cyanide furnace pots, can you advise me as to the maximum size practicable?

MR. TOPLIS: With reference to Mr. Gilbert's query in regard to the size of the cyanide pots and the material used, I quite agree that the larger size pots of mild steel pressings present difficulties. There is a limit which is somewhere about 16 inch to 18 inch diameter. Over this size most furnaces have cast iron pots, which, of course, are cheaper, but have a shorter life. The difficulties in many cyanide furnaces are due to the capacity being so small. Where the capacity is below requirements, it is best to have two or three small pots instead of one large size pot.

MR. SIDDALL (Member of Council): Do you not find that cyanide salts have some effect on the steel pots, a kind of decomposition of the steel, resulting in deposit? This seems more so in the case of some steels than in others. Also do you know of an annealing process sometimes termed "magnetic annealing"? One method is to heat the parts which are packed in boxes of sand to a temperature of 700° to 750°C., and allowing the boxes and furnace to cool down together? Can you tell me any better way of doing this?

MR. TOPLIS: Referring to your experience of deposits forming in connection with salt baths, I have not had any experience of this myself, but I should say that it is due to using the salt at a higher temperature than intended, and so it fluxes with the container or foreign matter in the bath. All salts have got a certain temperature range. A tempering salt fuses at 130° or 170°C., and may be used up to 530° to 540°C. For a temperature above that you must use a different composition of salt; for high speed steel, for example, a barium chloride type, used at 1250° to 1350°C., but at which temperature you get slight decarburising. Salts used at too low a temperature are sluggish and at too high a temperature there will be decomposition. I do not know the term "magnetic annealing."

MR. SIDDALL explained that the term was used by some manufacturers of electrical apparatus and was an annealing process to bring mild steel magnet cores to something like the consistency of Swedish iron for magnetic properties.

MR. HALES (Member of Council): I should like to have heard more in a wider range and I hoped to hear more about alloy steels rather than dealing in the main with case-hardened steels. We have troubles with case-hardening and we also have troubles with high tensile steels, particularly in obtaining the correct tensile strength. If we can standardise on the quality and characteristics of steels, we could obtain specified results.

MR. TOPLIS: With reference to Mr. Hales' remarks, I agree with him that modern heat-treatment is a tremendous subject and I was dealing mainly with matters affecting efficiency and output. With regard to "standardisation" of steels, there are hundreds of steels on the market with very slight differences of composition. We have internal specifications, and we have standard specifications duplicating one another. There are, however, manufacturing divergencies in steel made to the same specification. It is a great advantage to the user if the maker can tell you the life history—the pedigree—of the steel. The steel with the best pedigree is the most effective steel. Never buy solely on analysis—it is best to see how the steel is made. If you are buying large quantities the

steelmakers will welcome you. How the steel is made is the most important thing.

MR. PRYOR: With oil-hardened steel we have no troubles, only with case-hardening steels. Referring to the last speaker's remarks about modern heat-treatment, with case-hardening steels, it would be a great advantage if we could standardise the steel. I do a great amount of cyanide hardening and also carburising in boxes. Where you have to deal with over a thousand parts for production each week, every part has to be the same. Some firms run away with the idea that the selection of steel is not of great importance: it should be. They more or less expect the hardener to be a wizard.

MR. TOPLIS: He usually is (laughter). Mr. Pryor is quite right. The steel is chosen deliberately in consultation with the designer and the metallurgist. In some cases the advice of the hardener is taken. The hardener can do more than any other department to spoil all the efforts of the production engineer in a very few minutes.

MR. SUNDON: Will Mr. Toplis tell us something about "aero" hardening?

MR. TOPLIS: This relates to an American practice which is a substitute for the ordinary cyanide process. It is claimed that the fumes are not so troublesome. I have not, however, experienced many cases of distress through fumes, in ordinary cyanide practice, but I know of cases of injury through burns.

MR. CARRIER: I must say that I have thoroughly enjoyed this lecture and consider that Mr. Toplis has been very impartial. With reference to modernisation of heat-treatment equipment, we all know that most firms to-day are modernising their hardening shops. We have to-day in our own heat-treatment shops electric furnaces, gas furnaces, oil furnaces, and salt baths. For some purposes, such as annealing, we find that electric furnaces are most efficient, but for hardening we find that the quality of the work produced from a gas furnace is superior to that obtained from electric furnaces. Although in Sweden electric power is so cheap, all our new hardening furnaces in use over there are gas fired. It is a very desirable thing for us to have the automatic type of furnace which supercedes, for regular production, the ordinary muffle type of furnace. In such furnaces the gas and air pressures and proportion of gas and air must be maintained constant in order that the work hardened will be uniform and free from soft spots. The furnace is mechanically fed and the charge is weighed, and the rate of feed kept constant. If this is achieved, even automatic control may be found unnecessary, although it is essential, of course, to have an efficient pyrometric control.

MR. TOPLIS: Mr. Carrier has had a very wide experience. His remarks about hardening practice in Sweden were very interesting,

especially as hydro electric power should be very cheap. The reason why gas furnaces are preferred, is that, generally speaking, the use of air at atmospheric pressure for burning the gas gives a furnace atmosphere that is more bland and less likely to cause oxidisation. Electric furnaces can, however, be equipped with gas screens by means of which oxidisation may be cured. Mr. Carrier mentioned the weight of charge, the rate of feed and the time in the furnace as being of equal importance to, or even of greater importance than, temperature control. Undoubtedly it is, particularly on components of a mass production nature. Such practice can be and should be got down to a weight and time basis. The charge should be put into the furnace of the same weight every time. It is also necessary to provide efficient quenching arrangements. I should particularly like to thank Mr. Carrier for giving us the benefit of his experience.

MR. BROOMHEAD: I would like to ask regarding the size of the boxes to put the articles in. With large boxes you are heating up a greater mass of metal unnecessarily and taking longer to attain the required temperature inside the box. Does he find the depth of carbon penetration varying in pieces situated at different parts of the box? Does he know of any means of preventing this? Referring to the point raised by Mr. Hales regarding hardened bushes, the case where some cracked and some did not, I should think he is right in saying that the steel varied. It was entirely a matter for the people who supplied the steel, if he worked strictly to hardening instructions given to him.

MR. TOPLIS: If you use large boxes and put a pyrometer inside with the boxes, you will find that it is a very long time before the box is to the required heat. So, therefore, I think that the size of the box has to be determined by the size of the components. I do not agree with using large boxes for the sake of using them. It is realised that the smaller the box the better. Alloy steels are better than they used to be, and do not nowadays give much difficulty. But plain carbon steels still play a very important part. There is difficulty sometimes with .4 per cent. plain carbon steels which have to be heat-treated. To get regular results with oil quenching, temperatures of 860°-870°C. may have to be given according to the mass of the steel.

MR. MCLAGHLAN: Regarding the thermal efficiency and the design of furnaces, there ought to be a relation between the mass of brickwork and the size of chamber. With regard to carburising compounds, the question to be asked is, not what is the cost per cubic foot of compound, but what is the cost per .010 inch depth of case. As to boxes, I favour thick ones. Referring to the method of quenching parts out from the box, the question of the loss of compound should be taken into consideration. I should be grateful

for any improvement in the design of cyanide pots that would result in prolongation of their life. I am in favour of putting heat-treatment furnaces in line with the machines in the shops at the proper stages and operations for heat-treatment in line with production.

MR. TOPLIS : With reference to the thermal efficiency of furnaces, the nature of the brickwork has a very great effect on the radiation losses. If good insulating material or low conductive bricks are used extensively the radiation loss is brought down. With regard to compounds and the point you made as to the cost per unit depth of penetration, this is highly important, but I based my comparisons on compounds giving, theoretically, equal penetrations.

Respecting the use of thick alloy boxes there is the extra scrap value for heavier boxes, but after all, 4,000 hours is a long time to wait for this scrap allowance. Regarding quenching out from boxes and the consequent loss of compound you must take the time factor of quenching into consideration, for it is sometimes possible to empty the box into a riddle and so save some of the compound, but this is not always possible.

MR. BEDFORD : It is my privilege to propose a vote of thanks to Mr. Toplis for this very interesting lecture this evening. Mr. Toplis possesses a great sense of humour which has made it very interesting. I am sure that we have all learned something, as he has covered a wide field. I only hope that another opportunity of listening to Mr. Toplis will arise.

MR. TOPLIS : Thank you very much. I can assure you that it has given me great pleasure to give this lecture to you this evening.